# modern SCIENCE



DULL MANN

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## IN MAN'S PROGRESS

3

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# Preface

In this third book of the *Modern Science* series, the authors have used the same methods of presenting material as those they used in the earlier books. The aims and objectives of the series may be summarized as follows. The first book leads the pupil into an exploration of his environment to familiarize him with plants and animals; air, water, and fire; and the earth on which he lives — all of which constitute the stage for his daily work and play.

The second book focuses the attention of the pupil upon himself and his fellows. The human being occupies the center of the stage. Here the student learns something of his direct and indirect needs. He realizes how weather and climate affect him. He learns the value of clothing and the need to buy it wisely, clean it scientifically, and care for it properly. He finds out how the bodily house he lives in is constructed, how it functions, and how it can best be protected and repaired. The theme of the book is personal health and well-being.

This third book deals more largely with man's ambitions and his attempts to satisfy them. Pupils are now mature enough to be given guidance in how to study; the Introduction is devoted to this subject. In the opening chapters we find man reaching out beyond the earth to the neighboring planets, and also searching for knowledge of those far distant stars which may be the suns of other solar systems. The pupil recognizes the utter dependence of all terrestrial life upon our sun and its light energy, by means of which the food of all living creatures is made possible. The study of nutrients and vitamins naturally follows.

The pupil studies the home as a living center, and learns something of the kinds of houses men live in and how those

houses are built. He examines man's efforts to make his home more safe, more durable, more comfortable, and more livable. He follows the story of man's search for substitutes for the sun during the darkness, and discovers the part which light plays in his own visual processes.

This book deals also with the scientific progress man has made in using machines, in harnessing electricity, in inventing devices which enable him to communicate with very distant neighbors, and in using metals and alloys to build means of transportation across continents and oceans with speed undreamed of a century ago. The pupil learns how microorganisms are important to individual and community health. And, finally, he learns how man is developing new and more valuable plants, improving already useful animals, and attempting to raise human standards.

The amount of material included in almost any textbook in science today, especially in the broad field of general science, is greater than any one teacher will see fit to use. It is easier for the teacher to omit certain topics than to introduce topics not included. No attempt has been made by the authors to indicate which topics are to be stressed, but certain sections are starred as optional. The choice of textual material to be used must be left to the judgment of the individual teacher, who may be guided by local conditions. The teacher will find it easy to rearrange the sequence of units in order to satisfy seasonal demands, syllabus requirements, or personal preferences.

There are many pupil aids, including interest-arousing questions at the approach to each chapter; italicization of new words and terms the first time they appear; vocabularies with pronunciations and definitions; pronunciation and definition, within the text, of other scientific terms or difficult words. Accurate line diagrams aid in clarity of explanation, and attractive photographs show the broad scope of the sciences and the progress man has made.

# THE AUTHORS

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# Using Your Mind

In our earlier study of science we learned something of the things around us. We studied about the water that we drink, the air that we breathe, the fuel that we use for heat and energy, and the earth upon which we make our home. We studied plants and animals and found out how they depend upon each other. We learned how man uses both plants and animals to supply shelter, clothing, and food.

In our further study of science we have learned more about the parts of our environment that affect our daily life. We have spent some time also in learning about ourselves. We have learned how we use the oxygen of the air we breathe in, how we digest our food, how the digested food is carried by the blood to all parts of the body, how the body gets rid of wastes, and, most important of all, how to keep the body in good working order and in good health.

In this book we shall study the progress man has made by using science in all parts of his life: in locating himself in space and time; in feeding and housing himself; in using light

energy; in making machines work for him; in using magnetic and electrical energy; in transportation and communication; in controlling bacteria; in improving public health; and in producing new types of plants and animals. We shall begin our work by finding out something about the working of our own mind.

Did you ever think of how man created such things as the Pyramids, the Greek temples, and today's skyscrapers? How he discovered ways of producing and using electricity? Some human mind had to get an idea and develop it before any of these achievements were possible. Did you ever ask yourself why you behave as you do? How does your mind work? How do you use your mind as you study? These are all difficult questions. We find a partial answer to them in the study known as *psychology*. It is not an easy subject; but by studying some of the simple topics, we shall make at least a beginning in understanding it.

## *Think about these!*

1. It is easier to understand how a steam engine works than how the human mind works. Why do you think this is true?
2. In making an important decision, is it safer to depend upon your feelings or upon your carefully thought-out judgment?
3. How may a person acquire a good habit? How may a bad habit be broken?

## *Words for this introduction*

Sensation. A feeling which is caused by some stimulus.
Stimulus (stĭm'ū·lŭs). Something which excites or increases action in a living organism.
Emotions. Feelings such as joy, sadness, hate, love.

## *INTRODUCTION*

# *Using Your Mind*

**1. What is the work of the psychologist?** The scientist who makes a study of the human mind has a difficult task, because all human minds do not work in the same way. We do not even know exactly how the mind and the brain are related. A jeweler may take a watch apart, clean the parts, and put them together again. The watch will then probably keep good time. A botanist may pick a flower to pieces in order to study its various parts. A geologist may break up rocks to study them more carefully. A chemist may analyze a substance to find out what things are in it. [See Fig. 1.] But the psychologist cannot take apart the human mind to see how it works. He must experiment with different persons in the laboratory in an effort to learn how their minds act. He must expect to find many different reactions.

**2. What is the brain?** If we were to remove the brain of a cat in order to study it, we should find that it is made up of three main divisions: The *cerebrum,* the *cerebellum,* and the *medulla.* Your brain is similar to that of a cat. It is much larger, for it fills the entire upper portion of your head.

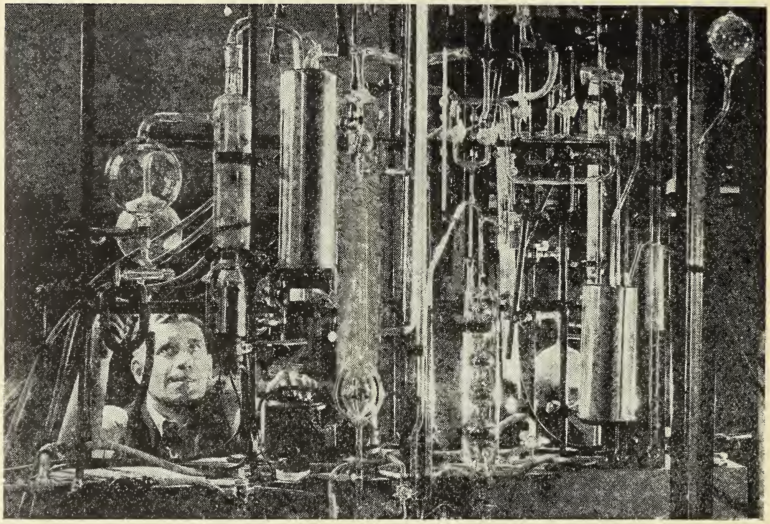


FIG. 1. Have you ever seen any apparatus of this kind that was made by one of the lower animals? The intelligence needed to make and to understand complicated apparatus is a marvelous faculty of the human mind. (*Courtesy du Pont Company*)

The bony cage called the *skull* is perched upon the upper end of the spinal column, which consists of twenty-four bones. These bones are separated by pads of *cartilage,* a gristle-like substance, which act as shock absorbers to keep the brain from being jarred too severely as we walk, run, or jump. The bones of the skull protect the brain from injury, and there are three separate membranes which surround the brain to nourish it and to help in its protection. The brain is the agent for the mind.

3. What is the mind? When a certain teacher was asked the question, " What is mind? " his answer was " No matter." When he was asked " What is matter? " he replied, " Never mind." He dodged the question in his attempt to be witty, but anyone might find it difficult to define *mind.* We do know that the mind is the center of all our thoughts. It is

the source of our will power. It receives impressions or messages which come to it through the five senses. It forms mental pictures which we call *images*. The mind keeps some of the impressions which it receives and thus makes it possible for us to remember things which we have seen, heard, or learned in any manner. The mind can also be the master of our feelings.

4. **What were some of the older ideas about our feelings?** Centuries ago the Romans believed that the various feelings were fairly well scattered throughout the body. They believed that the heart was the seat of the affections. The heart is the symbol of love that is used in our valentines, and it is the organ at which Cupid in his blindness is said to aim his arrows. We still use such expressions as "love with all my heart," "a loving heart," or "big-hearted" when we refer to someone who is kind and generous, although we now feel certain that the mind is the center of our affections.

The Roman poet Horace speaks of a person "whose raging liver boils with jealousy." The Romans thought that the liver was the seat of jealousy. Because the bile which is secreted by the liver is yellowish-green, either yellow or green is still used as a symbol of jealousy.

The *spleen*, an organ near the stomach, was thought to be the seat of anger. In one of his odes, Horace mentions a person who was "venting his spleen," an expression which means that he was giving way to anger.

5. **How does the mind form sensations?** A king on his throne may have spies, or intelligence officers, scattered all over his kingdom, or even in foreign countries. From time to time such officers send messages to the king to keep him informed of what is going on in different places. The king then sends orders to the officers, telling them what to do.

Like the king on his throne, the brain has messengers. These are the nerve centers and nerve endings all over the body. Possibly a book drops on your big toe. In some manner the nerve leading from that toe sends to the brain a message called an *impulse.* In some way, unknown to us, the mind interprets that impulse as a *sensation* of pain, and immediately the brain sends out an order to the muscle of the calf of the leg to take the toe away from danger. The cause, or *stimulus,* of this sensation was the dropping of the book on your toe.

Other impulses, interpreted in the mind as sensations, of which we become aware include heat or cold, touch, taste, smell, light, pressure, and sound.

**6. Does the mind remember?** Someone said of the English poet Oliver Goldsmith that he had a "wax brain." It was said that he never forgot anything. The sensations which his mind formed seemed to be engraved upon it, just as the *stylus* (stī′lŭs), or pointed part, of a phonograph cuts grooves in the wax of a master disc, or cylinder, and thus makes a permanent record.

When light passes through the lens of a camera and shines upon the plate or film, it brings about a chemical change and forms a picture which is usually fairly permanent. Some persons are said to be camera-minded. They look at a building or a landscape. [See Fig. 2.] A mental picture of that landscape is formed in the mind. If that picture is permanent, we say that the person has a good memory. If it fades out rather quickly, his memory is poor. If the mental picture fades out completely, we say that he has forgotten it. Some psychologists claim that the mind never really forgets anything. They say that we may seem to have forgotten some things, but that they may be recalled at some later time. You may have had the experience of trying to re-

FIG. 2. Exotic landscapes, such as this scene in the Sahara Desert in Algeria, are well worth remembering. (*Ewing Galloway*)

call something at a particular time, possibly during an examination, and finding yourself unable to do so. A half hour later, after you left the examination room, you may have recalled it without any trouble at all. One is accustomed to say, "It just came back to me." One who has a good memory and can recall things when he wishes to do so, is particularly fortunate.

7. How can you improve your memory? Have you ever heard a person say, "I cannot remember names"? We wonder whether his poor memory for names does not result from the fact that he pays little attention to the name when he hears it. The story is told of Napoleon that he never forgot a man's name. When he was introduced to a stranger, he listened carefully when the name was pronounced, and then wrote the name on a piece of paper. Then he threw the paper away. He had satisfied both his *ear memory* and

FIG. 3. Someone in this group of boys may be a genius. In the United States, all boys and girls have an opportunity to get an education. (*Courtesy New York City Board of Education*)

his *eye memory* or *visual memory,* as it is sometimes called. Perhaps he had strengthened his total powers of memory.

A pupil at one time offered the following excuse for his forgetfulness: "It went right in one ear and out the other." Was the teacher cruel when he suggested that a pupil of high-school age ought to have something between his ears which would offer some resistance? It was not poor memory on the part of that pupil, but lack of *attention.* [See Fig. 3.]

Have you ever said, "I'll never forget that experience"? In that particular case, your attention and interest were so firmly focused upon that experience that it made a lasting impression. If you would have a good memory, you must not think that any detail is too small to receive your attention.

Suppose that your teacher were to make the following announcement on the first day of the school term: "As a

Christmas present I always give each of my faithful pupils a five-dollar bill." Would such an announcement get your attention? Would it also arouse your interest?

A boy complains that he has a poor memory. He is a baseball fan. Ask him his favorite team in the American Baseball League. Ask him whether his favorite team won the pennant last season. If he says it did, then ask him whether that team won the World Series. It is probable that he can tell you by what score they won or lost. Ask some girl the same questions. The chances are that she has no interest in baseball and pays little or no attention to either the winners or the resulting scores. Possibly she would not know whether she should go to Detroit or to the Bronx to see the " Tigers " play the " Reds " in a series.

Ask a girl what six other girls wore at a dance held two weeks before. She can probably tell you the kind of material in each dress, its color, how it was trimmed, and whether it was a new dress or a last year's model. If you ask a boy the same question, you will learn that he wasn't interested and did not pay any attention. The memory groove may be shallow and fade out quickly, or it may be deep and permanent. You will do well to remember that the *attention-interest partnership holds the secret of a good memory.*

8. **How does repetition help the memory?** If you ever tried to teach a parrot to talk, you found it necessary to repeat the words again and again. Have you ever tried studying your lesson in the evening and then reviewing it the next morning? Such repetition is a valuable aid to memory. How did you learn the multiplication table? No doubt you repeated it again and again. By such repetition we seem to make such a deep groove in the channels of memory that we do not easily forget. The things that we committed to mem-

ory when we were only six or eight years of age usually made a lasting impression upon our minds.

9. How can we associate ideas to aid memory? Of course you know in what period of American history George Washington lived. In your study of history, do you associate with him such men as John Adams, Alexander Hamilton, John Hancock, Benjamin Franklin, and Thomas Jefferson? It will help you to remember the names of other men of that period if you associate them with Washington.

In studying foreign languages, you will find a vocabulary study easier if you can relate the words in some way to the corresponding English words. For example, our English word *night* is not unlike the French word *nuit* (nwē), the Latin word *nox,* or the German word *Nacht* (näkt).

Fig. 4. What association of ideas does this picture bring to your mind? (*Edwin Levick*)

Someone mentions the word *boat.* What association of ideas do you get? Do you think of a sail, a rudder, a pair of oars, an outboard motor, or a picnic near a lake? [See Fig. 4.] Each word may cause you to recall some other word or some former experience. A *key word* may sometimes start a whole train of ideas and memories. Someone mentions the word *vapor.* Possibly that word will call to mind in turn such words as *clouds, rain, stream, lake, ocean, waves, ocean vessels, storms, harbors, and docks.* Some persons memorize also by associating certain lines with their position on a page — at the top, near the middle, or at the bottom.

**10. Why is a good imagination desirable?** When our mind merely recalls an image which was produced as the result of a sensation, we are dealing with memory. But sometimes the mind combines two or more pictures or images to produce something entirely different. In such a manner the *imagination* goes at least one step further. The picture which the imagination gives us may be wholly fantastic. As examples, we think of the winged horse Pegasus and the centaurs, half man and half horse, from Greek my-

FIG. 5. As one reads Greek mythology, or looks at some of the pictures the Greeks conceived, he is impressed with the great activity and scope of their imagination. (*Courtesy New York Public Library*)

thology. Medusa (mė·dū′sȧ), with serpents in place of hair, and the three-headed Cerberus (sûr′bẽr·ŭs), the watchdog of Hades, are other fantastic products of the vivid imagination of the early Greeks. [See Fig. 5.]

The boy who sees a red stump in the woods and rushes home to tell his mother that he has just seen a half dozen foxes, has a vivid imagination. His love for the picturesque makes him an unreliable witness, but he should not necessarily be punished for telling a falsehood. He may not be deceiving his mother intentionally. The visual image he gets from the stump grows into a fox. His imagination magnifies it until it becomes several foxes when he tells his story. A too-vivid imagination leads to inaccuracy and is not good for scientific observations. When it weaves former experiences with one's observation, it may lead to fear and horror.

Have you ever read parts of *Gulliver's Travels?* Do you not think that the author of that book had a good imagination? First of all, Jonathan Swift had to form, in his mind's eye or imagination, an image or a picture of the Lilliputians before he could write their story.

The artist who paints a great picture must first have in his own mind, built up from his experiences and his imagination, a real image or picture of what he plans to create. Then he must transfer it to the canvas. If a novelist is to write a good story, he must have a good *constructive* imagination. In what we call his *mind's eye* he must have an image from which he constructs the plot of his story. Then he can fill in the narrative to fit his chosen plot.

How does an inventor make a new machine? First he decides what the machine must do. Then he builds his mental image of that machine. With the picture of the machine clearly in mind, he proceeds to construct a model of the machine. It is said that the man who invented the suspen-

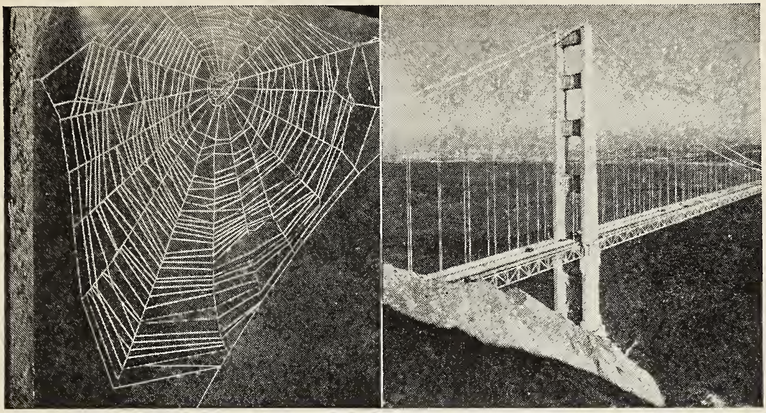


FIG. 6. The spider constructs a strong web, which appears to be woven with great ingenuity. What parts of the suspension bridge look like such a web?

sion bridge got his first ideas for the bridge by watching a spider spinning its web. [See Fig. 6.]

If there were no such thing as *creative* imagination, we would have no novelists, actors, poets, composers, painters, sculptors, architects, inventors, or landscape gardeners. A good actor must actually live, through his imagination, the life of the character he is portraying. A good novelist must create, or make real, for himself, the events that he writes about. Some excellent stories, too, have their strength in the fact that many circumstances and details are omitted, and must be filled in by the imagination of the reader.

11. **Why is it dangerous to play tricks on the imagination?** During a fraternity initiation, a young man was told that his appendix was to be removed. He was first blindfolded, strapped upon a table, and his *abdomen* (ăb·dō′mĕn) was then bared. A pointed icicle was drawn across his skin above the position of his appendix. Warm water from a rag flowed down over his side and was permitted to drip, drip, drip into a pail of water beneath the table. In the mean-

time, members of the fraternity commented among themselves upon how freely he was bleeding. When the pretended operation was over, its planners were horrified to find that the young man had died of fright, the victim of too vivid an imagination. Such extreme initiations are dangerous and are now forbidden by law.

It is never wise to tell a sick person that he looks ill. His imagination is almost certain to make him worse. As a practical joke, four persons conspired to work upon the imagination of a friend, Andrew Stone, and make him sick. When the first person met Andrew in the morning and told him that he did not look well, Andrew paid little or no attention. A half hour later a second person met him and told him that he looked as if he ought to be in bed. Then Andrew began to think that he was not feeling well. After a third and a fourth person had told him in turn how ill he looked, he went home, got into bed, and called a doctor. It is easy to work upon the imagination of others, but it is unsafe to do so. It is almost certain to cause worry, unhappiness, or even actual injury.

**12. Is will a mental faculty?** By far the larger number of our muscles are under the control of the will. One may act or he may refuse to act. The will power is a faculty of the mind, but the mere fact that a person has a strong will is not necessarily proof that the person has great mental ability. Some persons mistake " won't power," of which the donkey is a classic example, for will power. [See Fig. 7.] Unless one has the will to do, however, he can never develop a strong character. The mind must judge what course to follow, and the will must supply the persistence necessary to success.

No parent or teacher should attempt to " break " the will of a child. He is likely to find the child as stubborn as the

FIG. 7. Which do you think will win in the end, the "will power" of the intelligent-looking boy, or the "won't power" of the stubborn-looking donkey? (*Courtesy Arizona Highways Dept. — Chuck Abbott Photo*)

man who took shelter under a large tree during a thunderstorm. When lightning struck the tree, the man was knocked flat on his back. He jumped up, planted his feet firmly, and said, "I will stand here." More can be accomplished by reasoning with the child, and attempting to show him that his stubbornness may lead him to wrong habits. In the old legend, the wind is said to have suggested to the sun that he could force a man to remove his coat. The sun believed that violence would fail, but that gentler methods might succeed. The wind then blew furiously, but the man merely buttoned his coat and drew it about him the more tightly. Then the sun turned on his gentle rays. As the warmth increased, the man removed his coat. The gentle sunshine succeeded where the blustery wind had failed.

13. **How are habits formed?** If a mother permits a child to suck his thumb as he goes to sleep, she finds later that the child has formed a habit which is difficult to break. A child plays with his toys, and then rushes away after he has finished his play, leaving his mother the task of putting his

toys away. That child is forming careless, slovenly habits. He can easily be trained to put away his own toys when he has finished his play.

Doing a thing in the same way, over and over again, is likely to become a habit. As the habit grooves become deeper and deeper, they become more and more difficult to break. It has been said that if we take the letter *h* from *habit,* we still have *a-bit* of it left. If we remove the letter *a,* the *bit* of the habit remains. Even when the letter *b* is removed, *it* is still left. Only when you take the *i* out of your habit will you reach the end of it.

**14. How can one overcome bad habits?** The easiest way to stamp out a bad habit is to substitute for it a good one. In order to avoid slovenliness, one must practice neatness at all times. It is a good rule to have a place for everything, and always to keep everything in its proper place. [See Fig. 8.] That pupil who learns at an early age to keep his papers neat and orderly is probably not asked to copy them. The

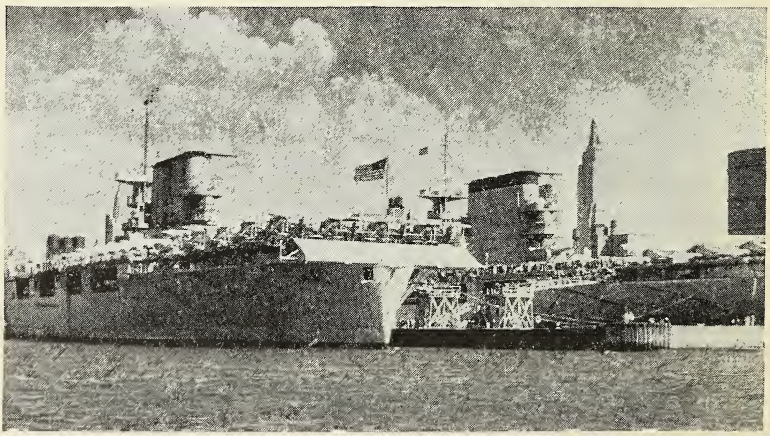


FIG. 8. Aircraft carriers are perfect examples of a plan for everything, and everything in its place. Neatness is essential to economy of time and space. (*Douglas from Gendreau*)

pupil who forms a habit of using a definite time each day to study a particular lesson rarely fails to be promoted.

The habit of using drugs or stimulants such as coffee, tea, alcohol, or tobacco is somewhat different, since they weaken the nervous system and the will. Almost any smoker will tell you that smoking is an expensive habit and that it is injurious to the throat and lungs. Why doesn't he stop smoking? Probably he has found that tobacco is a habit-forming drug, and that it takes too much will power to break the tobacco habit after it is once formed. If you never begin to smoke, you will never feel the necessity for breaking the tobacco habit.

The sipping of a cocktail from time to time is likely to lead to the use of alcoholic liquors, often to excess. It is claimed that at least three persons out of every ten who form the habit of taking alcohol will eventually drink to excess. You are in no danger if you persistently refuse to take your first alcoholic cocktail or your first drink of any alcoholic beverage. Few persons have the will to break the habit of using alcohol, even when they find that it may cost them their jobs, because alcohol deadens the entire nervous system, including the brain itself.

15. **How does man differ from the animals?** In feats of strength, man must yield to the horse, the bull, the lion, and many other animals. In tests of speed, man is easily beaten by the rabbit, the cat, the dog, the deer, or the horse. The eagle seems to have better sight than man, and it is said than an elephant never forgets a kindness or an injustice. In length of life, man cannot compete with the parrot, the turtle, or the alligator.

But man has two advantages over animals. He is able to *reason.* He thinks over his problems, and forms judgments. He has the ability to compare one judgment with another to

see which is more reasonable. The ability to reason is the highest mental faculty, and we do not know of a single animal so capable of reasoning as man. Because man has that faculty, he has become an inventor. Man alone makes machines which can be used to multiply his feeble efforts or to increase his speed. Man's second advantage is his possession of a wonderfully flexible hand. He can use the tools that his mind invents. No animal uses tools to do his work or to protect himself.

**16. How early does the human mind begin to work?** The sensations of touch, sight, taste, smell, and hearing come to us early in life. The feelings of pain, pleasure, hunger, anger, love, and hate all begin to appear shortly after a child is born. In fact, young children feel some things keenly, and make little effort to hide their feelings.

A young child remembers well if his mother rocks him to sleep for several nights, and then decides not to do so any more. A child memorizes words readily and learns languages easily. For that reason some persons suggest the study of foreign languages in the elementary schools.

The imagination, too, is developed early in life. A child weaves one experience into another and sometimes gets fantastic results. He enjoys hearing stories, and soon learns to tell stories which he has composed himself.

The ability to think clearly is not developed so early as are the other mental abilities. The ability to form accurate judgments and to compare them in the process of reasoning is the highest of the mental faculties. Naturally, it is not at its best early in life. Your ability to solve problems should grow better and better as you grow older. Your reasoning power is not likely to be at its best before you are an adult. The Indians had a motto: "Old men for counsel; young men for war."

17. What is your purpose in school? Nature has endowed you with a large number of little gray cells, or what is called "gray matter." Your mental ability seems to depend upon them. Your main purpose in school should not be to see how many facts you can memorize, in mere parrot fashion; but many facts must be memorized if you are to have a foundation upon which to build. You can train your memory, too, and improve it.

You will do well to remember the words of Samuel Johnson, "Knowledge is of two kinds; we know a subject ourselves, or we know where we can find information upon it."

If you wish to do any creative work at all, such as painting, drawing, writing, or modeling, you must train your imagination along creative lines. You must build a constructive imagination. [See Fig. 9.]

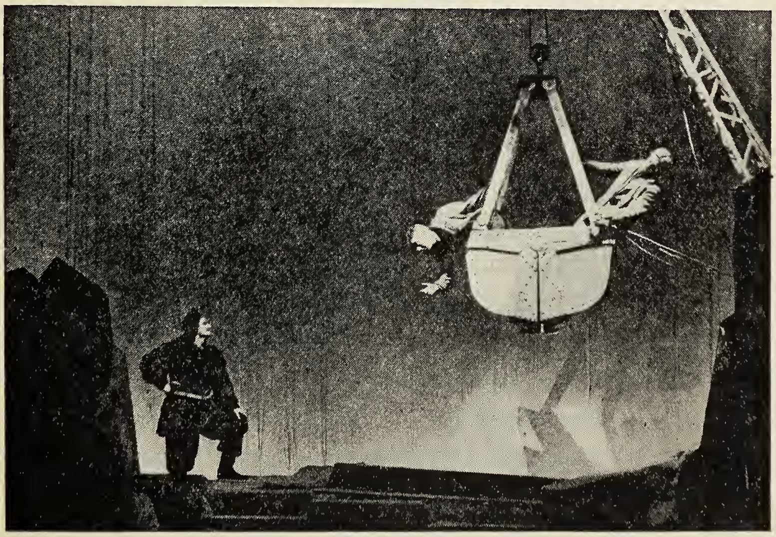


FIG. 9. Students constructed this realistic-looking steam shovel for Maxwell Anderson's play, *High Tor*. The boulders, too, were designed and constructed by students. How did imagination play a part in this construction? (*Courtesy Antioch College*)

You will need to guard your feelings and your *emotions,* because you will find them more easily swayed than your judgments. A lawyer for the prosecution in a criminal case plays upon the emotions of the jury. He tries to show that the defendant is an evil character, deserving no sympathy whatever. The lawyer for the defense may point out the fact that the man never had a real chance, that he deserves more pity than blame, and that his wife and children will suffer if he is punished. Would you be won over by this kind of argument?

Your main purpose in school will be to train the able mind with which nature has supplied you, to learn to think a problem through carefully, to form accurate judgments from sets of data (dā′t*ȧ*) or figures, and to draw logical conclusions.

**18. How can you improve your methods of study?** Some pupils never really learn how to study to good advantage until they are nearly through high school. It is possible that you, too, are not forming good study habits. Some of the suggestions given here may be of help to you.

**19. Can you read rapidly?** Within the past few years, a number of books have been written about reading. Some of these books give exercises for helping readers to increase their speed, as well as exercises for reading at different speeds for different purposes. You can understand that you would read a story of adventure more quickly than you would read a chapter in your social-studies textbook, and you can understand that you would skim rapidly if you were looking in your history for the date of some happening. [See Fig. 10.]

Do you read faster or slower than your classmates? Perhaps your teacher will give the class a time test, starting all the group at a certain time, and recording the number of minutes each one requires to read the same passage. As each

FIG. 10. How quickly should you read directions for making a cake? Would you read faster than if you were reading a story? (*Philip D. Gendreau*)

pupil finishes, he will raise his hand; and the teacher will then write on the blackboard the number of minutes or minutes and seconds that pupil required.

Another way to measure your reading speed is to secure one of the magazines in which a certain number of minutes is set for reading stories or articles in it — just as in some newspapers a time is set for working a cross-word puzzle. Is your reading time slow, as shown by such figures? Many pupils of high-school age read very slowly, and many of them read poorly, too. If you have a room to yourself, it will help your reading if you spend some time each day in reading aloud. Then you should try reading *silently* with greater speed.

**20. Do you read intelligently?** In an effort to read rapidly, you may fail to read intelligently. You may read words without understanding them. How can you tell whether you are understanding what you read? Here is one way. Read a paragraph at your usual speed, close the book, and

check yourself by asking questions about the paragraph. If you can give the *gist* (jĭst), or meaning, of the paragraph, you have read with understanding.

In a chemistry class a girl made the following statement: "Bismuth is used in making fusible alloys." Her teacher asked her the meaning of the word *alloy*. She did not know. Then he asked her the meaning of the word *fusible*. She did not know. Isn't that the kind of recitation one would expect a parrot to make — a mere repetition of words? If you are to read intelligently, you must not skip any word whose meaning is not clear to you. Have at hand a dictionary, and use it frequently.

When you look up the meaning of a word in the dictionary, you should observe how it is spelled, you should notice how it is pronounced, and you should learn what it means. Then it will really become your own word. You will be less likely to forget it if you use the word in a sentence every day for a week. If you wish to be really thorough, you will notice from what language the word is derived, or how it came into being.

Intelligent reading means, first of all, reading with understanding. But it means something more. It means forming opinions as you read a passage, or seeing the connection between the passage and earlier passages, or seeing the relation between the passage and some part of your own experience or knowledge. If you are reading in your American history a paragraph describing the construction of the Union Pacific Railroad, you can test yourself for intelligent reading by two methods. First try to give the gist of the passage; then see whether you have made any comments about it to yourself. If you can give the gist and if you find that you have thought, "Well, that was hard going," or "The country certainly needed that railroad," or "Traveling was so much harder

FIG. 11. Passengers in 1830 rode in trains like this. (*Courtesy Baltimore and Ohio Railroad*)

then than it is now," or something similar, then the chances are that you have been reading intelligently. [See Fig. 11.]

**21. Do you find definitions troublesome?** Are you one of the pupils who are likely to say: "I hate definitions"? Suppose you are asked to define *botany*. You know that it is one of the sciences. You know also that it deals with the study of plants. Are we wrong, then, if we say that botany is that science which deals with the study of plants? You will find it easier to give good definitions if you ask yourself two questions: to what class or group does the thing belong, and how does it differ from every other thing in that group?

Let us apply those questions in making a definition for the word *man*. (*a*) To what class does he belong? Man is an animal. (*b*) How does he differ from other animals? He reasons. We are not wrong, then, if we say that man is an animal that reasons far better than any other animal.

How do we define *oxidation?* (*a*) To what class does it belong? It is a process. (*b*) How does it differ from other processes? It is the uniting of oxygen with some other substance. Then we put the two together to make the following definition: Oxidation is the process of uniting oxygen with some other substance. In "Some Things for You to Do" (No. 2) at the end of this Introduction, you will find a group of words which you should be able to define without using a dictionary.

**22. What shall you try to remember?** You may wish to memorize, word for word, some poems or your favorite parts of some poems. It is foolish, however, to try to memorize what you study for an assignment. A part of almost every paragraph is explanatory. It is intended to explain the other portions so that you will be sure to grasp their meaning. In your study, you should practice reading such explanations until you are certain that you know what the paragraph really means. Then you may forget many of the words in the textbook, and make the explanations in your own words.

In your textbooks you will also find examples which help to make the underlying principles clear to you. You should first read the examples, and then try to think of others dealing with the same principle.

What you really need to grasp and remember is the principle. When it is possible, you can add your own explanations and give your own examples. Then you will not "clutter up" your memory, and at the same time you will be training yourself to think.

**23. How can you solve problems?** No one has been able to find an easy way to solve all numerical problems, but possibly we may be able to find some methods which are easier than others. [See Fig. 12.] Here are some suggestions.

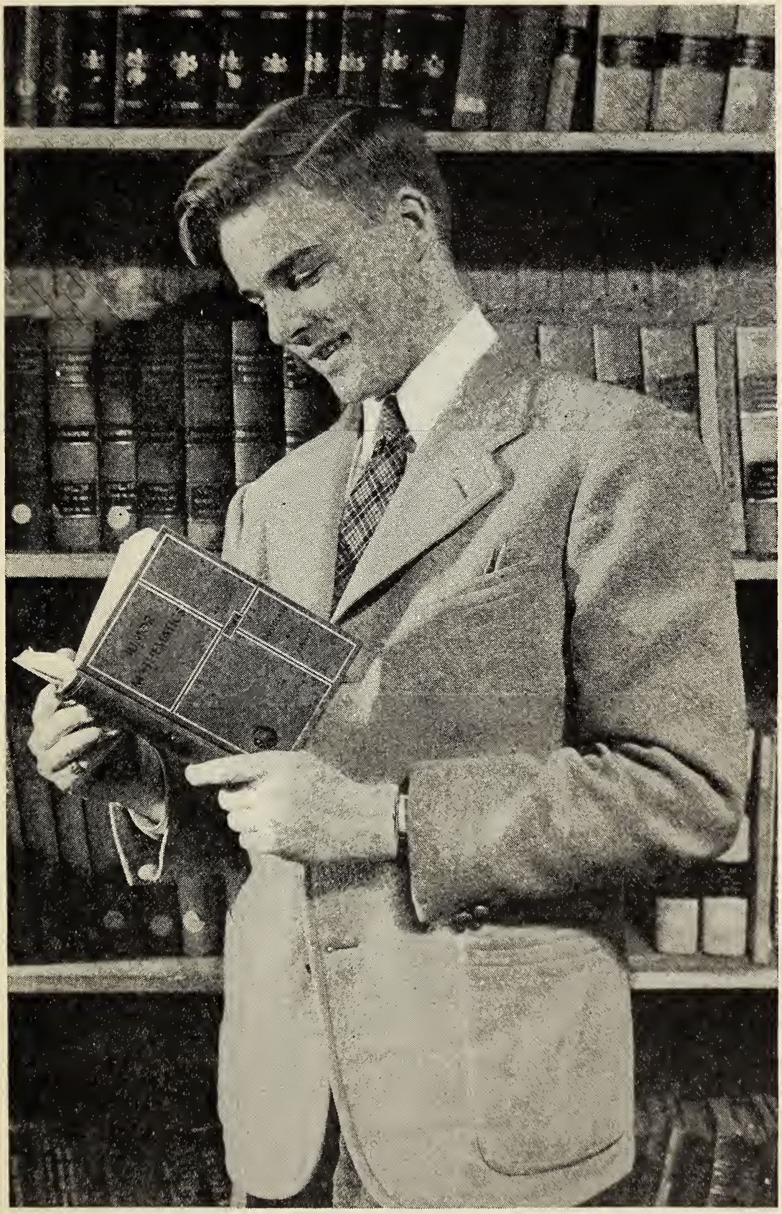


FIG. 12. It is possible to study mathematics and like it. (*Philip D. Gendreau*)

(*a*) It will pay you to read a problem twice to be sure you understand it. (*b*) Then you may jot down on a piece of paper, neatly, all the different facts and figures that are given. (*c*) Ask yourself what is unknown, or required. (*d*) You are now ready to ask yourself, "What does my judgment tell me to do to find the answer? Shall I add, subtract, divide, or multiply?" (*e*) Do the work that you decide upon. (*f*) Finally, ask yourself whether the answer you get seems reasonable. A girl was trying to calculate an electric-light bill for one month. She got for her answer $22,500. Do you think that her answer was reasonable? A boy was asked how much deeper a flatboat would sink in water when an elephant was taken aboard. He got an answer of 33,000 feet. The correct answer to that problem was *eight inches.*

24. **Should you study alone?** It is desirable for every pupil to have a room where he can study alone, undisturbed by the radio or by other members of the family. A few pupils find their study so interesting that they are not bothered by ordinary conversation in the room, but they are exceptional persons.

There are some occasions, too, when it is helpful to discuss with someone the topics or problems which you find in your lesson. The great objection to two persons' studying together is that one of them is usually a better student than the other. The stronger pupil does the work and grows still stronger. The weaker pupil becomes less and less self-reliant. He grows weaker and depends more and more upon someone else. One must learn to be independent if he is to avoid becoming a mental cripple. He may not always have his crutch with him.

25. **Can you learn to concentrate?** Have you ever read a paragraph and immediately afterward been unable to tell

FIG. 13. How easily can you concentrate on work that must be done? Is it easier to concentrate on a routine task, like practising, or on something new? (*Courtesy Wm. Knabe and Company*)

a thing about it? Possibly you just came in from playing basketball and your mind was still on the game. Unless you are a genius, you cannot divide your mind enough to put part of it on one task and part of it on another, and do both of them well. [See Fig. 13.] It is easy to say, "Put all your mind on your study when you study, and all of it on your play when you play." But not everyone can concentrate so well as Socrates, the famous Greek philosopher. The following story is told about him: "Socrates was seen, standing barefooted on the ice for two hours, oblivious to his surroundings, completely absorbed in a problem of which he was thinking."

When you find your mind wandering off to something else, you may lay aside your book, go outdoors, and walk rapidly once or twice around the block. It is probable then that

when you sit down to your study, you can concentrate upon your work. It is a good plan, too, to keep checking yourself from time to time by closing your book and asking yourself a question about what you have just read. Good study habits will conquer poor ones, but only if you keep trying.

26. Do you suffer from lack of interest? Did you ever hear one of your classmates say that he did not find a particular subject interesting? It is probably true, too, that almost every pupil finds some subjects more interesting than others. Possibly you feel that some of the things you study in school are of little value to you. Have you ever said, "Why do I have to learn that?"

A high-school student went to his English teacher and told him that he thought the study of Keats' poem "The Eve of St. Agnes" was useless and uninteresting. It is a beautiful poem, but rather fanciful. A few days later the same boy handed his English teacher an editorial which had been written to show the uselessness of studying in school such poems as "The Eve of St. Agnes." The boy said, "You see that the editor of the paper agrees with me." When the teacher asked him whether he had enjoyed the editorial, he replied, "You bet I did!" Then the teacher asked, "Do you think you would have enjoyed the editorial if you had never studied the poem?" The boy thought a minute before he said, "You win."

In school we study some subjects because they have practical value. At some time they may help us to earn a living. We study some subjects to learn how to improve our health and that of the community. Other subjects which we study help us to develop hobbies for our leisure time. [See Fig. 14.] Still other subjects help us to become better citizens of our community. Some of us study art, music, and poetry for the enjoyment and appreciation which they afford us. It is a

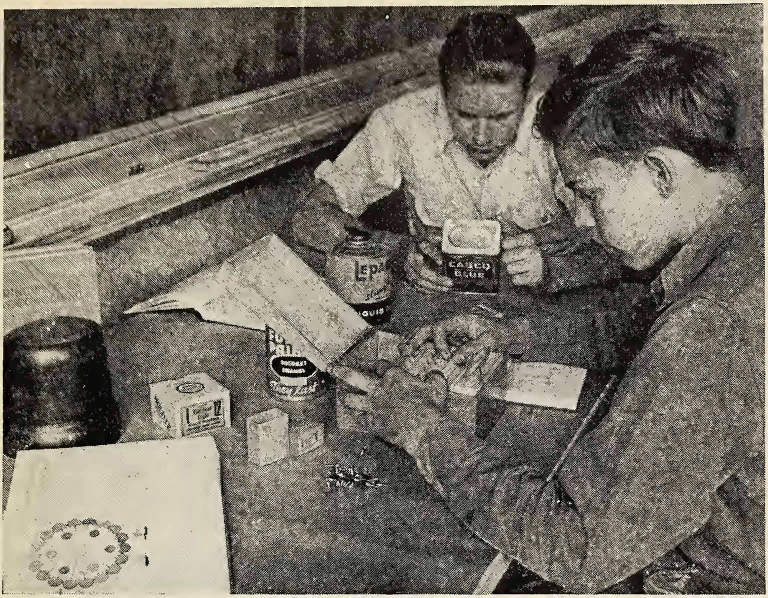


FIG. 14. Do you have a hobby? Have you ever made a collection of stamps, flowers, old birds' nests, rocks, shells, or butterflies? (*Courtesy Los Angeles City Schools*)

source of satisfaction, too, to be able to answer a question which some person may ask. We all admire John Kieran and envy his ability to answer correctly so many of the questions asked on the " Information, Please " hour.

Can you ever afford to be inattentive because you are not particularly interested in every subject which you study? Inattentiveness and lack of interest are likely to lead to the formation of bad mental habits, one of which is daydreaming.

27. Are mnemonics helpful? The awkward word *mnemonics* (nė·mŏn′ĭks) means a device intended as an aid to memory. It may be a word or name made up of the first letters of a list of words one wishes to remember. For example, protein is composed of sulfur, phosphorus, carbon,

oxygen, hydrogen, and nitrogen. The name *S. P. Cohn* is a mnemonic which is made up of the first letters of the names of the six most important elements found in protein.

In physics, the word *vibgyor* (vĭb′gyôr) has been coined to help pupils remember in order the names of the colors of the rainbow: "violet, indigo, blue, green, yellow, orange, and red." You see that the name *vibgyor* is made up of the first letter of each word in the list.

In music, if one is playing in sharps, he *sharps* only one note in each octave when playing in the key of G; in the key of D, he sharps two notes in each octave; in the key of A, he sharps three notes in each octave, and so on. [See Fig. 13.] In the sentence, "Good deeds are ever bearing fruits," the first letter of each word represents the keynote in sharps. The number of the word in the sentence tells how many notes are sharped in each octave.

At one time mnemonics were largely used in an effort to aid the memory, but their value is now considered rather doubtful.

**28. Is learning by rhyme useful?** It is possible that your grandmother learned a little jingle to help her remember the capitals of all the states in the United States. It was not uncommon to use such rhymes in her childhood days. It is possible, too, that she learned another to help her remember the names of the presidents in order.

Learning by rhyme seems to be of little value. It may even turn out to be a disadvantage. One girl said she could never remember dates, not even when Columbus discovered America. She was given this rhyme:

In fourteen hundred and ninety-two,
Columbus sailed the ocean blue.

The next day she was asked when Columbus discovered America. She gave the rhyme as follows:

In fourteen hundred and ninety-three,
Columbus sailed the deep blue sea.

29. **How can you use references?** Have you ever felt that you would like to know more about some topic than is given in your textbook? If so, how can you supplement the material given in the text? The field of knowledge is so vast that any author finds it a difficult problem to know what to omit from the text.

The use of the dictionary has been mentioned as almost indispensable. You will probably find a good encyclopaedia in your school library. It is placed there for reference. You will doubtless find, too, many other books dealing with your required topic. Many magazine articles are both helpful and interesting. If you have not yet learned how to use the *Reader's Guide,* you should consult the librarian in your school or the librarian in the public library of your town or city, and ask her to show you how to look up articles from the *Reader's Guide*. The museum is also a valuable source of information.

## *QUESTIONS*

1. In what ways is the brain protected against injury?
2. Why does the color green or yellow represent jealousy?
3. About how long does it take for your brain to receive news of an injury to your toe, and to send out an order?
4. Why do we often think of the sense of touch as being located in our fingers? Where else is it located?
5. What is meant by saying that Oliver Goldsmith had a "wax brain"? Do you know of any person whom you might describe in a similar way?
6. What can you do to improve your memory? What is the attention-interest partnership, and how can it help you?

7. Have you known or read about any person with too vivid an imagination? If so, describe that person and explain why his or her imagination was too strong.

8. Why is it dangerous to play jokes or tricks upon a person through his imagination?

9. Suppose that a boy has formed the habit of reading rapidly without understanding what he reads. What method would you suggest for him to use in breaking himself of the habit?

10. Can you give an instance of reasoning by an animal other than man?

11. Do you study with another pupil? Is this pupil a better student than you are? Do you think it helps you to study in this way? Explain your answers.

12. Young persons are usually skillful in driving cars. Why do you think that young men between seventeen and twenty-five years old have more accidents than an equal number of men between thirty and thirty-eight?

13. Do you enjoy the "Quiz Kids"? Do you envy them?

## *Some things for you to do*

1. Write a paragraph of 150 words or more about several things that you expect to learn during this school year — things that you believe will be useful to you later in your life.

2. Using the method outlined in section 21 for forming definitions, but without referring to a dictionary, write definitions for the following words: *geography, sled, arithmetic, automobile, lawn mower, volcano, hammer.*

3. Make a list of good study habits that you would like to recommend to a younger brother or sister.

4. How well does your imagination work? Give it a tryout by writing a possible autobiography for a penny which has been in circulation for ten years.

5. If you can secure a copy of *Let's Read!* Book II or Book III, by Roberts and Rand, read several selections in it. What is your reading rate? Can you answer the questions at the ends of the selections?

# Man Explores the Solar System and the Starry Sky

As the shepherds of the past guarded their flocks by night, they watched the stars and planets. They knew the visible planets by name and could find them at different seasons. They knew certain groups of stars by the names which had been given to them at some early time: the mighty hunter, the large dog, the small dog, the ram, the bull, the great bear, the little bear, and many others named because of an imagined likeness.

If one of these early shepherds returned to our world and visited the parts of it which most clearly show man's progress – skyscrapers, power plants, laboratories, broadcasting towers, for example – the returned shepherd might feel that night was more familiar than day; at night he would at least see familiar objects in the sky.

He would find, however, that even if there was relatively little change in the skies, man had changed enormously in his attitude toward the heavenly bodies. Since the time of

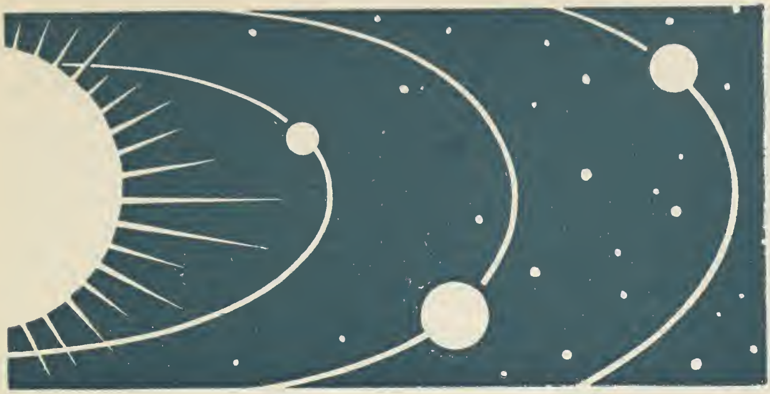
the early shepherds, the modern science of astronomy has been born. The telescope has been invented. Man has learned that it takes light about four years to reach us from the star nearest our sun. He has calculated that light from some of the more distant stars must have taken millions of years to reach the earth. He knows that the earth is but a dot when compared with the solar system, and that the solar system is merely a fragment of the universe. But despite these enormous sizes and distances, man is as closely connected with the heavenly bodies through clock and calendar and map, as any of the early shepherds watching the familiar constellations above their fields of sheep.

## *Think about these!*

1. What is the solar system, and of what does it consist?
2. Is the sun a star? Why is the sun so important?
3. Is it reasonable to be terrified when a comet approaches the sun?

## *Words for this chapter*

**Revolve.** To travel in a path around some object.
**Asteroids.** Small planets.
**Horsepower.** Rate of doing work. One horsepower is the amount of work done in raising 550 pounds one foot per second.
**Rotates.** Turns on its axis.
**Axis.** An imaginary straight line passing through a body, on which that body supposedly rotates.
**Poles.** Either end of the axis of any heavenly body.
**Gravitation.** That force which attracts two bodies to each other.
**Nebula** (nĕb′ū·lȧ), plural **Nebulae** (nĕb′ū·lē). A cloudlike mass of stars.
**Ellipse.** A closed curve like a lengthened, or elongated, circle.
**Foci** (fō′sī), plural of **focus.** The points used in drawing an ellipse.
**Centrifugal** (sĕn·trĭf′ū·găl) **force.** A force pulling from the center.



CHAPTER 1 ______________ UNIT 1

# What Is the Solar System?

**30. What is the solar system?** The shepherds in the past, as they watched their flocks by night, had plenty of time to study the stars. They noticed that many *constellations,* or groups of stars, were always seen in the same relative position with respect to one another. Long ago many of these constellations were named for animals which they were supposed to resemble, or sometimes for early Greek heroes or other legendary characters. For example, we have Canis Major (the Great Dog), Ursa Major (the Great Bear), and Taurus (the Bull). The constellations of Orion and Hercules are also well known.

The early observers noticed, too, that several heavenly bodies, which in many ways resemble the fixed stars, were seen in different relative positions from night to night. At one time such wanderers were seen in one constellation, and a few weeks later they were seen in another one. Such wanderers were called *planets.*

Five planets were known to the ancients, who named them for the Roman gods — Mercury, Venus, Mars, Jupiter, and Saturn. Now we know that the earth too is one of that group

of planets which revolve around the sun as a center. When Galileo, the great Italian philosopher and scientist, invented the telescope, he made it possible for men to see much farther into space. By its use three more planets have been discovered: Uranus (ū′rȧ·nŭs), Neptune, and Pluto.

The sun is the center of our solar system, and the nine planets we have named *revolve* around it, each in a path, or *orbit,* which is nearly circular. Of course there may be other planets which are still farther from the sun than Pluto, which is the farthest of the nine we know. Pluto was not discovered until 1930.

Some of the planets have *moons,* or *satellites* — bodies which revolve in nearly circular paths about them. The earth has one moon; Mars has two small ones; Jupiter, the largest planet, probably has eleven moons; Saturn has several rings and at least ten moons; Uranus has four satellites; and Neptune has one. So far as we know, the other planets have no satellites.

The solar system also includes several hundred small bodies known as *asteroids* or *planetoids,* a large number of *meteoroids,* and an unknown number of *comets.*

*31. **What was Ptolemy's idea of the solar system?** It is interesting, sometimes, to study the ideas believed by people who lived centuries ago. It was about A.D. 140 that Ptolemy (tŏl′ē·mĭ) of Alexandria, Egypt, worked out what he believed to be the plan of the solar system. He assumed that our earth was the center of the solar system and that the sun and the then-known planets all revolved around the earth. For nearly fourteen centuries this explanation of Ptolemy was considered correct. An old astronomical clock, standing for many years in Prague, Czechoslovakia, pictures on its face the solar system as Ptolemy believed it to be.

32. **Where did we get our idea of the solar system?** In 1543 Copernicus (kō·pûr′nĭ·kŭs), a great European scholar, published a new theory of the plan of the solar system. He proposed the idea of a *moving earth* and a *fixed sun,* in direct

contradiction to Ptolemy's idea of a *fixed earth* and a *moving sun.* In his books he writes: " In the middle of all stands the sun, and who could wish to place the lamp of this most beautiful temple in another or better place? Thus, in fact, the sun, seated upon his royal throne, controls the family of the stars which circle around him."

Nearly everyone now accepts this view of Copernicus, although his ideas were bitterly opposed at that time. Many of the leaders of the Catholic Church looked upon his ideas as sacrilegious (săk′rĭ·lē′jŭs), or as violating their religious beliefs. Galileo accepted the beliefs of Copernicus and was threatened with *excommunication,* or expulsion, from the Church unless he gave up his belief in the theories of Copernicus. Galileo said that the leaders of the Church would be convinced too if they would come and look through his telescope.

If you look at Figure 1–1, you will see the sun as it stands in the center of the solar system. Revolving around the sun at varying distances are the nine planets. As the planets revolve around the sun, the moons revolve around the planets.

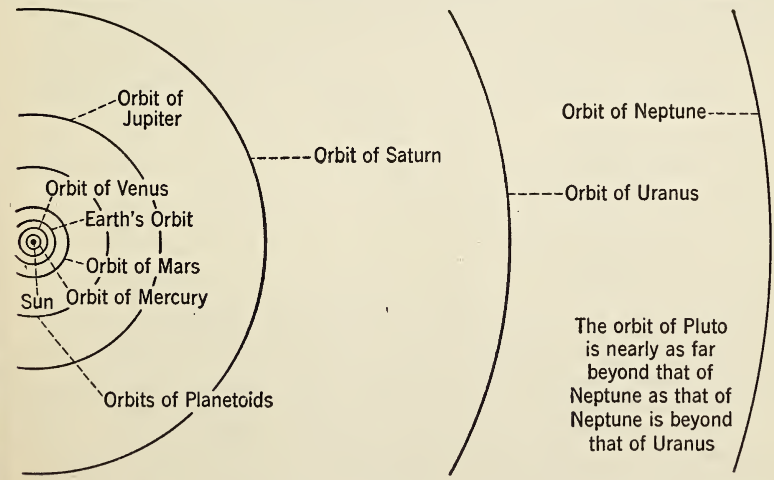



FIG. 1–1. The relative sizes of the orbits of the planets are shown here.

When we think of the solar system, we think of the sun and the family of planets. The sun is really a star, but it is also the center of our solar system.

33. **How much do we owe to the sun?** In order to get a good idea of how much we really owe to the sun, let us try to picture what would happen if the sun were blotted out. Almost immediately we should be plunged into nearly total darkness. The moon would no longer give us any light, because it merely reflects to us some of the light which it gets from the sun. The temperature of the earth would fall rapidly until it reached several hundred degrees below zero. There would be no heat energy to evaporate any water. Water areas would be frozen solid. Plant life would die. Animals would soon starve, or perish with the intense cold.

For *light*, for *heat*, and for *energy* we depend upon the sun. The energy from the sun enables plants to make food for themselves and for animals. The energy which we get from coal and petroleum came from the sun, too; the plants from which both coal and petroleum were formed grew upon the earth millions of years ago with the aid of the sun. The energy which we get from water power, too, comes originally

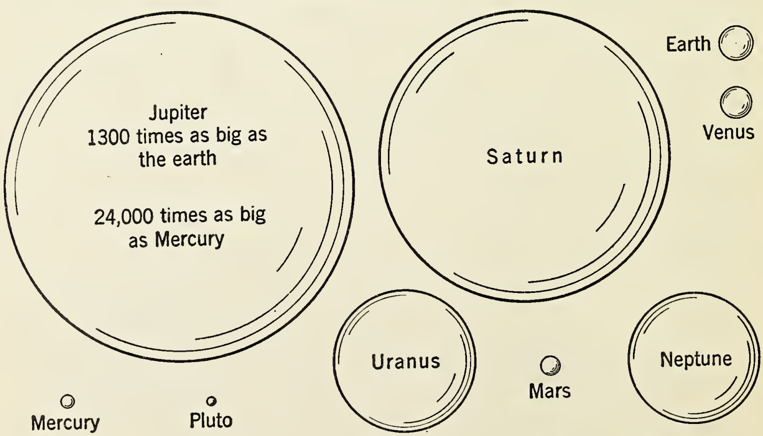



Fig. 1–2. This diagram shows the relative diameters of the different planets.

from the heat which is needed to evaporate water; and this heat, too, can be traced to the sun. Figure 1–2 shows the relative diameters of the various planets.

34. **How big is the sun?** This huge ball is so big that it would be possible to carve from it 1,300,000 balls the size of our earth. Its diameter is more than 100 times the diameter of the earth, or a total of 866,000 miles.

Let us use another illustration. Suppose the sun were hollow and the earth were placed at its center. The moon, which is about 240,000 miles from the earth, could still continue to revolve around the earth inside of the sun, and it would still be 200,000 miles away from the inner surface of the sun's hollow shell. [See Fig. 1–3.]

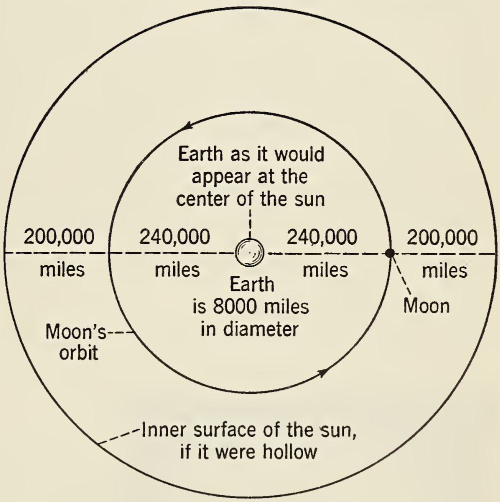



FIG. 1–3. Our earth may seem very large to us, but if we compare its size to that of the sun, we find that it is really very small. The earth looks lost when placed beside the sun.

35. **What other facts are known about our sun?** You may be astonished to learn that the sun is a huge mass of gas. The gases of which the sun is composed are so highly compressed that they are actually a little denser than water.

The temperature of the sun's surface is estimated to be 10,000° F., or perhaps even more. No one knows much about the temperature of the interior of the sun, but it is believed to

be as much as 1,000,000° F. It has been calculated that the energy given off from each square yard of the sun's surface is equal to 70,000 *horsepower.* The entire earth receives less than one two-billionth of the light and heat energy which the sun yields. The rest of it goes off into space or to some other planet. No one knows for how many million years the sun has been giving off light and heat. It is rather gratifying to us to know that astronomers do not believe that the sun is slowing down very much in the amount of heat and light energy it releases.

**36. What are sunspots?** Galileo, and some of the other men who lived at the same time that he did, were the first to observe the dark spots which appear upon the sun's disc from time to time. They are really not very dark, but they appear dark in contrast to the exceedingly bright portions of the sun's disc. Their temperature is probably nearly 2000 Fahrenheit degrees lower than the temperature of the areas which surround them, yet they are brighter than any artificial light source that we know. Sunspots vary in size; some have a diameter of a few hundred miles, and others have a diameter of 50,000 miles. They are probably huge masses of whirling gases, somewhat similar to our cyclonic storms, but much larger. [See Fig. 1–4.]

By watching sunspots, astronomers have found that the sun

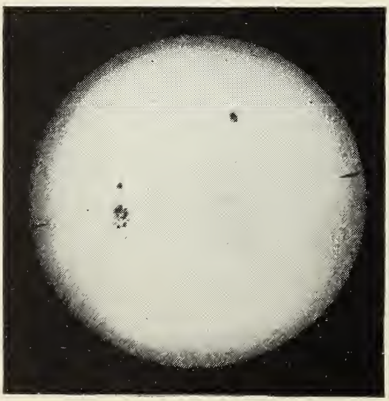


Fig. 1–4. Spots appear upon the surface of the sun from time to time. They seem to come and go without any apparent reason. It seems marvelous that they are capable of affecting our radio reception and our telegraph communication. (*Courtesy Mount Wilson Observatory*)

*rotates* on its *axis* in from 25 to 27 days. At different latitudes on the sun the time needed for the spots to rotate around the sun varies. This fact is further proof that the sun is gaseous. If the sun were solid, all the spots would rotate at the same speed. It is interesting to note that sunspots are much more common at some times than they are at other times. They may occur at any time, but they are much more numerous at intervals of about eleven years.

The astronomer George Ellery Hale showed that sunspots act like huge magnets. It seems hardly possible that sunspots which are about 93,000,000 miles away could have much effect upon the earth. However, it has been known for a long time that spots on the sun do produce magnetic disturbances upon the earth. When sunspots are large and numerous, we may expect to have communications by telegraph and radio disturbed greatly. Weather is also affected.

**37. How do the planets differ?** The nine planets vary decidedly in size, in their relative distances from the sun, in the time it takes for them to rotate on their axes, and in their *periods* – the time that it takes them to revolve around the sun. Some have no satellites, and others have from one to ten, or possibly more. In this chapter we shall discuss briefly eight of the planets. From our point of view, the earth is so important a planet that it merits a separate chapter. The table given on page 56 shows what the astronomer calls the *elements* of the sun and the planets.

**38. Mercury — the messenger of the gods.** Although this planet is the smallest of all, yet we can see it with the naked eye because it is not very far distant from the earth. It is the nearest planet to the sun. Because it is only about one-third as far from the sun as is the earth, one square yard of the surface of Mercury receives almost nine times as much heat and light as that received by one square yard of the earth's surface.

Like the Roman god Mercury, who was the wing-footed messenger of the other Roman gods, this planet *speeds* around

the sun, making an entire revolution in only 88 days. On Mercury, one year would be equal to 88 of our days. But we are certain that there is no life as we know it on this planet.

Mercury can be seen as an evening star in March and April, and as an early morning star in September and October. It is so close to the sun, however, that in the spring it sinks below the horizon soon after the sun sets, and it appears above the horizon in the fall only a short time before sunrise.

39. **Venus — twin sister to our earth.** For seven or eight months of each year, Venus appears as an evening star. Then it disappears for a few weeks, after which it can be seen as a morning star in the east before the sun rises. When seen with the naked eye, Venus at its best is the brightest planet.

Venus is almost the same size as the earth, and about two-thirds as far from the sun. This planet receives more than twice as much heat and light as does the earth. When Venus is on the same side of the sun as is the earth, it is less than thirty million miles from the earth. It revolves around the sun once in 225 of our days.

Venus has an atmosphere that is about as dense as ours, and it seems always to be filled with clouds. Because the surface of this planet is hidden by clouds, it cannot be seen by means of a telescope. The planet remains a mystery, and we do not know whether or not there is life on the planet Venus.

40. **What planet is without a proper name?** The third planet in order of distance from the sun is one which you have never seen in the sky. It is the planet on which you live. No Roman god was honored by having his name applied to this planet. It is called the earth, and it is our home. In size it is only slightly larger than Venus, and its distance from the sun is about 93,000,000 miles. It rotates on its axis once a day and revolves around the sun once a year. It has one satellite, which we call the moon.

41. **Mars — the red planet.** Probably because it has a red appearance, this planet was named for the god of war. Its diameter is just about half that of the earth. Mars and Pluto

are about the same in size. Mars is about one and one-half times as far from the sun as is our earth; therefore it must receive less than half as much heat and light per square yard of surface as the earth does.

Mars rotates on its axis in 24 hours and 37 minutes. Hence its day and night are about the same length as ours, but its year is much longer. Mars makes a revolution around the sun in 687 days. Mars has two very small satellites, or moons.

*Is Mars inhabited?* No one has yet found a satisfactory answer to this question. Mars has an atmosphere, and there seems to be water vapor in its atmosphere. For these reasons life on Mars seems to be possible. When Mars is seen with a telescope, blue-green markings on an orange background can be seen. While the reddish-orange color is thought by some to be desert regions, yet other markings can be seen too, which are thought to be areas of marshy ground or of vegetation. Some white patches at the *poles* may possibly consist of huge ice caps similar to those in the polar regions of the earth. [See Fig. 1–5.]

Much excitement arose when an Italian astronomer, about fifty years ago, announced that he had discovered markings which look like channels connecting the so-called " seas " of Mars. The idea that they may be artificial canals used to conduct water from the melting caps to the desert or arid areas

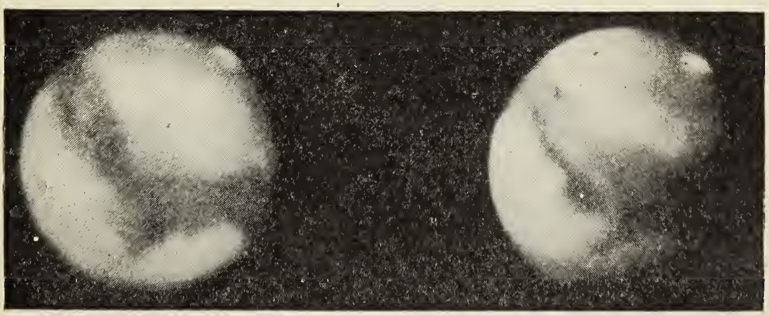


FIG. 1–5. Man has always been interested in the planet Mars. He is continually wondering whether this planet can possibly be inhabited. (*Courtesy Mount Wilson Observatory*)

on Mars was suggested. Such an idea, however, is not generally accepted by astronomers.

It does seem possible that a being who was accustomed to a much rarer atmosphere and a much colder climate than ours, could live on Mars. Possibly you recall that many persons took seriously the radio drama of Orson Welles when he described an attack on the earth by the inhabitants of Mars. No one can positively say that Mars is inhabited, but even if it is, you may feel absolutely safe from any attack from its inhabitants.

**42. Jupiter — the giant planet.** Like the ruler of the gods for whom it was named, Jupiter is the mightiest of the planets. Jupiter is more than 1300 times the size of the earth, and is larger than all the other planets and their satellites combined. This planet is more than 88,000 miles in diameter, and its average distance from the sun is a little more than five times the distance from the earth to the sun. Jupiter spins on its axis at a terrific speed, making a rotation in less than ten hours, but it takes almost 12 years for this great planet to make one revolution around the sun. If you had lived on Jupiter during the time it took 14 earth-years to pass, you would be only beginning your second Jupiter-year.

The surface of Jupiter appears very cloudy, and the clouds seem to be banded together near the equator. The temperature at the surface of the planet is believed to be too low for

FIG. 1–6. As one looks at Jupiter, shining so brightly, he can understand why the planet was named for the supposed ruler of the gods of the ancients. This large planet is believed to be large enough to capture comets and deflect them from their orbits. (*Courtesy Mount Wilson Observatory*)

water vapor to be formed, and the cloudy appearance is not believed to be due to water vapor. When seen with the naked eye, Jupiter looks brighter than any star except our sun, but it is not so bright as the planet Venus when that planet is at its brightest. [See Fig. 1–6.]

In 1610 Galileo, with his telescope, saw four of the satellites of Jupiter. Ganymede (Găn'ĭ·mēd), one of the largest of the satellites, has a diameter of 3200 miles. It is somewhat larger than the planet Mercury, and it can be seen with the aid of a pair of good field glasses. Jupiter, with its family of probably eleven satellites, resembles the sun, with its family of nine planets. By observing the times of the eclipses of one of Jupiter's moons from the earth at different positions in its orbit, Roemer was able to calculate the velocity at which light travels.

**43. Saturn — the ringed planet.** This planet, if seen with the unaided eye, looks like a yellow star of great brilliance. When viewed through a telescope, Saturn is one of the most interesting and beautiful objects in the heavens. It has three rings and a family of ten satellites. The entire ring system is 171,000 miles in diameter. [See Fig. 1–7.] These rings consist of swarms of very small solid particles, something like tiny satellites.

Saturn has a diameter of 74,100 miles, which is a little more than nine times the diameter of the earth. Its distance from the sun, too, is more than nine times the earth's distance from the sun. It takes Saturn 29½ years to make one revolution

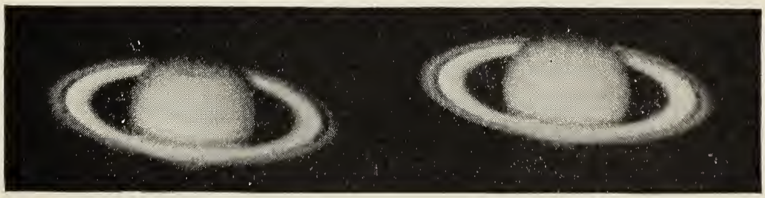


Fig. 1–7. To get a really interesting view of the ringed planet one needs a telescope. The planet is seen at its best when the flat side of the rings faces the earth. (*Courtesy Mount Wilson Observatory*)

around the sun. Thus, if you are 14 earth-years of age, you would be less than a half-year old if you had lived from birth on the planet Saturn.

Although the earth as a whole is more than 5.5 times as dense as water, yet the entire planet Saturn has so low a density that it would float on water, if one could find an ocean large enough to contain it. The largest satellite of Saturn is Titan (tī'tăn), which is almost as large as the planet Mercury.

**44. Uranus — the planet named for the heavens.** This planet was discovered accidentally by Sir William Herschel. He loved astronomy as a hobby, and built his own telescope. While he was "sweeping" the heavens with his seven-inch reflecting telescope, he discovered this planet, which he named *Uranus.*

Uranus has a diameter about four times that of the earth, but it is so far away that it is barely visible to the naked eye. It is about 19 times as far from the sun as is the earth, and it takes 84 of our earth-years for this planet to make one revolution around the sun. Uranus has four satellites, the largest of which is called Titania.

**45. Neptune — the planet named for the god of the sea.** In many respects this planet resembles Uranus. It is somewhat larger than Uranus, and about a billion miles farther from the sun. It takes almost 165 years for Neptune to make one revolution around the sun. What would your age be, if it were based upon a year on the planet Neptune? Only one satellite belonging to Neptune has ever been discovered.

**46. How was Neptune discovered?** The beginner in astronomy is likely to be amazed when he reads that one heavenly body is a billion miles from another, or that Neptune is about two and three-quarter billion miles from the sun. Then he is likely to become doubtful and consider all such figures nothing but guesswork. Later he learns that astronomers can predict the times of eclipses within a second, even for hundreds of years in advance of the time of their occurrence. He finds that the discovery of Uranus was acci-

dental, but learns that the discovery of Neptune came as the result of careful mathematical calculations.

When Uranus did not follow the precise path in its orbit that their calculations showed it should follow, astronomers began to suspect that there was an undiscovered planet out beyond it and still farther from the sun. Uranus behaved as if some large body out beyond its orbit were pulling upon it by the force of *gravitation* and making it change what was regarded as its normal course.

Two astronomers, Adams in England and Leverrier (lĕ·vĕ′-ryā′) in France, undertook the work of calculating exactly where an undiscovered planet would have to be in the heavens to produce the effect upon Uranus which had been observed. Do you not agree that it was a hard problem which they set for themselves? When Leverrier finished his calculations he wrote to Galle (gäl′ĕ), an astronomer at the Berlin Observatory, and told him where to point his telescope in order to find a new planet. Galle did as he was directed, and within a half hour he had found a new planet, to which the name *Neptune* was given. That happened in 1846. The next time you feel scornful at some of the figures given out by astronomers, take a few moments to consider this great triumph for mathematical astronomy.

**47. Pluto — the most distant planet.** In 1915, the American astronomer Percival Lowell calculated the orbit of a new planet beyond Neptune, in much the same way that Adams and Leverrier had calculated the position of the planet Neptune. For years astronomers searched for such a planet. It was discovered by observers at Lowell Observatory, at Flagstaff, Arizona, on March 13, 1930, and was named *Pluto*.

Little is known about Pluto, since it is so far distant that its exact diameter cannot be measured. It is almost certain that Pluto is smaller than the earth, possibly more nearly the size of Mars. Its average distance from the sun is 3,670,000,000 miles, and it takes 248 years to make one complete revolution around the sun.

**48. What are the asteroids?** These small planet-like bodies were first called *asteroids* (starlike bodies) by Sir William Herschel, who discovered a large number of them. There are thousands of these small planets revolving around the sun, in an orbit that lies between the orbits of Mars and Jupiter. The brightest of them have been named. For example, Ceres, Pallas, Juno, and Vesta were discovered early in the nineteenth century. Vesta is bright enough to be seen without the aid of a telescope. By the end of the nineteenth century, more than 500 had been discovered, and at the present time more than 1000 are known. Most of them are very small, probably ranging from 25 to 500 miles in diameter.

Nothing is definitely known concerning the origin of the asteroids. Some persons have expressed the opinion that they form the remains of an exploded planet. Other persons think they may be the parts of some *nebula.* They revolve around the sun in from 3 to 8 years. One of them, Eros, is the nearest neighbor which the earth has, if we except the moon. The asteroids are often called by the name *planetoids.*

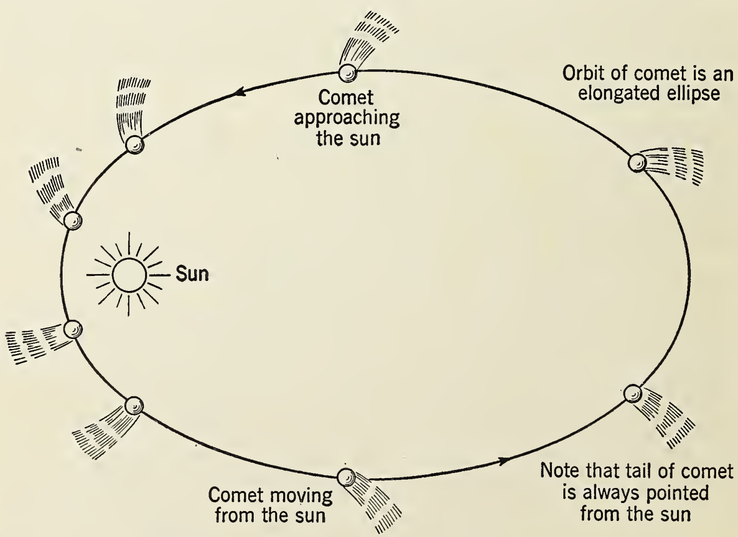



FIG. 1–8. What remains unchanged about the comet's position?

**49. What are comets?** Some of the comets seem to be members of the solar system family, and others probably are merely visitors. Those which belong to the solar system have orbits which are elongated *ellipses*, with the sun at one of the *foci* of the ellipse. [See Fig. 1–8.] Halley's comet, which comes so close to the earth every 76 years that it is visible to observers, is believed to have a very much elongated orbit. Some of your family may have seen Halley's comet in 1910, when it approached the sun, rounded it, and then started away again on its long journey. By the year 1948, it will have rounded the farthest end of its orbit and be starting back to the sun for its next visit. Some comets have periods which are only a few years in length.

The head of a comet is usually from five to twenty times the diameter of the earth, and its tail is millions of miles long. The head of a comet may have a starlike center, which is believed to be made up of rather small bodies, widely separated

Fig. 1–9. This comet was discovered by the astronomer Brooks in 1911. (*Courtesy Yerkes Observatory*)

from one another. The tail of the comet always streams away from the sun, probably because it is pushed away by the pressure of the light. [See Fig. 1–9.]

Ignorant and superstitious persons have always looked upon comets as objects of awe or of danger. At one time comets were considered omens of war or of pestilence. Some persons fear that a large comet may collide with our earth. When large comets, bright enough to be seen in the daytime, appeared in the past, calamities were predicted. Even in 1910, it was predicted that the earth would pass through the tail of Halley's comet and that the peoples of the earth would be smothered with harmful gases. The comet came on scheduled time and followed its predicted course, but no one was poisoned by gases. Although it is possible that a comet may at some time collide with the earth, it is not very probable. The tail of a comet is composed of gases that are *rarefied,* or decreased in density, and are so thin that it is doubtful whether they could ever penetrate our atmosphere enough to reach the lower parts in which we live. Your chance of being poisoned by the gases in a comet's tail is almost zero.

**50. What is a meteor?** No doubt you have seen, on clear, starry nights, flashes of light which enter our atmosphere, and seem to shoot across the sky. Such so-called "shooting stars" are not stars at all, but particles of matter of varying size which come near enough to the earth to be pulled toward it by the force of gravitation. As such particles fall rapidly through our atmosphere, at a velocity of from 10 to 40 miles per second, they are so highly heated by friction that they become incandescent. They are usually oxidized, or burned up, in the air; and the firelike ball leaves as a trail a shower of sparks. Professor Newton estimates that from 10,000,000 to 20,000,000 small meteors, or shooting stars, enter our atmosphere every day. It is probable that their average weight is less than one ounce.

Meteors may come from particles within the solar system or possibly far beyond it. Some meteors apparently come

from comets or from the tails of comets. The history of Biela's Comet seems to confirm this view. This comet, which had a period of 6.6 years, was discovered in the year 1826. It reappeared twice as a comet, but in the year 1846 the head had split into two parts. In the year 1852, the twins appeared again, but they were at that time about 1,500,000 miles apart. The comets have never been seen since that time. In the year 1872, however, as the earth was crossing the path of the lost comet, there occurred a wonderful shower of meteors. The same thing occurred in 1885, and again in 1898. It seems probable that these meteors were at one time a part of Biela's comet. As one astronomer remarked: "Biela's comet appears to be shedding its fragments upon us." Other meteoric showers have been observed.

**51. What is a meteorite?** Sometimes the meteors, which are attracted toward the earth, are too large to be entirely oxidized or burned in their passage through our atmosphere. Then they may fall and bury themselves in the earth. Such a fireball leaves a long train of sparks, and it may burst like a rocket, forming an explosion or a series of explosions. That

FIG. 1–10. When such a meteorite falls, it may bury itself in the earth to a considerable depth. Here we see a man getting ready to remove the Hugoton meteorite.

part of a meteor which reaches the earth as a rocklike mass is called a *meteorite.* The ending *ite* in English comes from a Greek word which means *stone.* Sometimes a meteorite may fall as a single piece, or sometimes " it may rain stones."

Meteorites vary in size from a few pounds to several tons. Several large meteorites were found in Greenland a number of years ago. They were brought to New York City, where they may now be seen in the Hayden Planetarium. Some of the meteorites are composed almost entirely of iron and nickel, but at least thirty other elements have been found in meteorites. [See Fig. 1–10.]

**52. How was the solar system formed?** This is another of those questions to which astronomers do not really know the answer. Astronomers have at times tried to explain the origin of the solar system by various *hypotheses.* An hypothesis is a little better than a scientific guess. One hypothesis assumes that the solar system came from a huge nebula composed of intensely hot gas, or possibly of some solid particles. This nebula is believed to have been formed when our sun and some other star came so close to each other that the force of gravitation partially pulled one or both of them apart. As the other star moved on, it set the smaller pieces spinning, twisting, or rotating around the main central portion.

Scattered throughout such a whirling, nebulous mass there would exist knots of nebulous matter of varying sizes. Such knots of matter would attract to themselves other particles, just as meteors are drawn toward the earth even at the present day. The larger masses would form the planets; and the smaller masses, the satellites. Such bodies would continue to rotate and revolve, the planets around the sun as a center, and the satellites around the planets. Some large spiral nebulae can be seen with the aid of the telescope. It is possible that they are new solar systems in the making. The great spiral nebula of Andromeda (ăn·drŏm′ē·d*ȧ*) is so far from us that it would take light from Andromeda, traveling 186,000

Fig. 1–11. This huge nebula furnishes a picture of worlds in the making. From a different part of the sky it would appear spiral.

miles per second, over 800,000 years to reach our earth. Yet this nebula is so large that it can be seen with the naked eye. [See Fig. 1–11.]

**53. How are the parts of the solar system held together?** When you drop a ball which you have been holding, it falls to the earth. We call the force which pulls such objects to the earth *gravitation.* The force of gravitation was not discovered by Sir Isaac Newton, but he did give us the *law of gravitation,* which tells us two things. (*a*) The force of attraction between any two bodies is *mutual* and *universal.* That means that a falling brick is attracted by the earth and that the brick attracts the earth too. It means, too, that the force of gravitation is not limited to the earth, but that all bodies in the universe attract one another.

*b*) The force of attraction between any two bodies decreases if we increase the distance between them. In fact, it

is only one-fourth as great at a distance of 2000 miles as it is at a distance of 1000 miles. No one can explain what the force of gravitation really is, but it is easy to prove that such a force exists.

If gravitation were the only force that acts in the solar system, then the planets and their satellites would quickly fall into the sun. If the force of gravitation is pulling them all together, what keeps them apart? To answer this question, let us perform a simple experiment. Suppose we have a ball with a hole drilled through it. We fasten one end of a string to the ball. If we hold the other end of the string firmly in one hand, and then swing the ball around our head, we can feel the ball pulling on the string and tending to break it. Such a pull by a ball revolving in this manner is called *centrifugal force*. [See Fig. 1–12.] It is the force that keeps

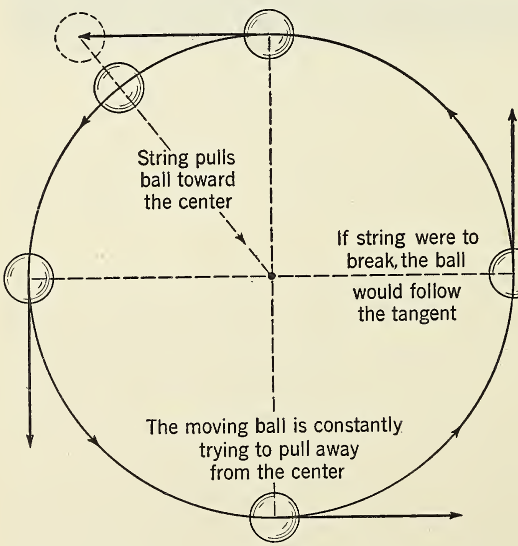



FIG. 1–12. Centrifugal force tends to break the string and pull the ball away from the center about which it is revolving.

the water from flowing out of the bucket when we rotate a bucket of water, upside down, in a circular motion above our head and down again. It is the centrifugal force which tends to pull an automobile off the road when that automobile is

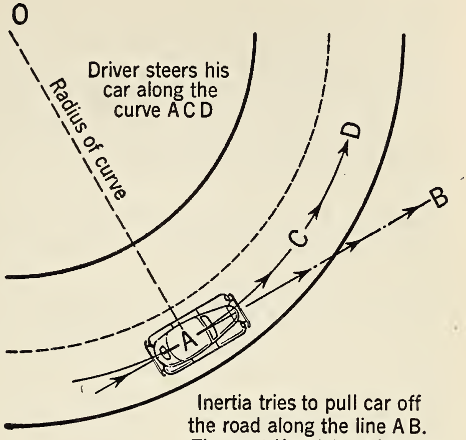



FIG. 1–13. The inertia of an automobile attempts to pull it from the road as it rounds a corner. Such a property of inertia is called centrifugal force. It increases as one increases the velocity of a car. It decreases as we increase the length of the radius of the curve.

rounding a curve at high speed. [See Fig. 1–13.] This force increases with the weight of the object, and it increases as we increase the velocity. As the earth, for example, revolves around the sun at a speed of well over one million miles per day, its centrifugal force tends to pull it away from its nearly circular orbit and to make it fly off into space. Thus we have *two opposing forces.* Fortunately for us, there is an exact balance among all those forces which holds the planets and also the satellites in their orbits. If centrifugal force were to weaken, we would start at once on a trip to the sun. If the force of gravitation were to weaken for an instant, we would start off on a journey into uncharted space. It does not appear likely that the forces will become unbalanced and cause such a catastrophe.

54. Some facts arranged in tabular form. The following table may be used as a summary of certain facts that are known about the various planets. This table is useful for reference, but it is not expected that the pupil will attempt to memorize all the facts and figures that are given. The question mark used with the data concerning Pluto indicates that the figures are not accurately known. You must remem-

ber that the planets move in orbits that are ellipses, not true circles. Hence their distance from the sun varies. The earth, for example, is only 91½ million miles from the sun in January and it is about 94½ million miles away in July. The table shows average distances:

THE ELEMENTS OF THE SUN AND THE PLANETS

| Name | Average distance from sun in millions of miles | Diameter in miles | Time of revolution | Time of rotation | Number of satellites |
|---|---|---|---|---|---|
| Sun | .... | 866,000 | .... | 25 da. | .... |
| Mercury | 36 | 3100 | 88 da. | 88 da. | None |
| Venus | 67.2 | 7700 | 225 da. | 225 da. | None |
| Earth | 92.9 | 7927 | 365¼ da. | 24 hr. | One |
| Mars | 141.5 | 4215 | 687 da. | 24 hr. 37 m. | Two |
| Planetoids | 200–400 | 10–485 | 3–8 yr. | Unknown | None |
| Jupiter | 483 | 88,640 | 11.86 yr. | 9 hr. 55 m. | Eleven |
| Saturn | 886 | 74,100 | 29.5 yr. | 10 hr. 14 m. | Ten |
| Uranus | 1782 | 31,000 | 84 yr. | 10 hr. 45 m. | Four |
| Neptune | 2793 | 34,000 | 164.8 yr. | 15 hr. 48 m. | One |
| Pluto | 3670 | 4200(?) | 248 yr. | Unknown | None |

## QUESTIONS

1. Name the planets in the order of their sizes.
2. A pupil is fifteen years old. Calculate his age, if he lived on each of the other planets, using that particular planet-year as a basis.
3. How many balls, each the diameter of the earth, must be laid side by side to equal the diameter of the sun?
4. What is the law of gravitation?
5. How can one tell a planet from a fixed star?
6. Name the nine planets in the order of their distance from the sun, beginning with the nearest.

7. An aviator, flying day and night, at an average speed of 208 miles per hour, can encircle the earth in 5 days. At the same rate, how long would it take to encircle the sun? How long would it take to fly to the sun?

8. How does a meteor differ from a meteorite?

9. What are some of the reasons for believing that there may be life on the planet Mars?

10. What are some of the reasons for believing that life cannot exist on the planet Mercury?

11. What do you think would happen to us if the earth paused for a few minutes in its path around the sun?

## SOME THINGS FOR YOU TO DO

1. Using the *Reader's Guide,* look up a magazine article which describes the discovery of Pluto. Make a report for the class.

2. Make a chart which shows the nine planets with their relative sizes.

3. Astronomers use the average distance of the earth from the sun, about 93,000,000 miles, as a yardstick. Using a scale of one-fourth inch to equal 93,000,000 miles, draw circles to represent the orbits of the earth, Mars, Jupiter, Saturn, Uranus, and Neptune. How large a radius is needed for the orbit of Pluto?

4. In an astronomy textbook or an encyclopedia, read an explanation of the Nebular Hypothesis. Be prepared to give a report upon it.

5. In an astronomy textbook look up the theories which attempt to explain why the sun continues to give out heat and light energy in such great quantity.

## *Think about these!*

1. Do you know how to find the North Star?
2. Are the stars five-pointed? Why do you think they are usually so drawn?
3. What is a constellation? Which is your favorite constellation? Why?

## *Words for this chapter*

**Meridian.** The highest point reached by a heavenly body in its course; a true north-and-south line.
**Spectroscope.** An instrument used to produce spectra.
**Spectrum, plural Spectra.** A band of colors formed by separating the colors present in white light.
**Galaxy** (găl′ǎk-sĭ). A great cluster of stars, the Milky Way, for example.
**Latitude.** Angular distance from a circle of reference; distance north or south of the equator.
**Magnitude.** Referring to the brightness of stars. First-magnitude stars appear to be very bright.
**Equilateral.** Having sides of equal length.


CHAPTER 2 ——————— UNIT 1

# Why Is Our Study of the Stars and Constellations Useful?

**55. What are the stars?** Not only children but older persons too have wondered what the stars really are. The question was asked by early observers, who noticed that the stars seem to be fixed with respect to one another, and that the planets are the wanderers. For example, let us refer to the Big Dipper. Probably you know where to look for it and how to find the North Star. [See Fig. 2–1.] If you watch the Big Dipper for several nights in succession, you will observe that the bright stars which form the Big Dipper are always in the same position with respect to one another. It is a good plan to look at the Dipper at the same hour each evening. You will observe that all the stars have the same position with respect to one another. Those stars which form the Dipper all seem to revolve around the North Star. They only appear to do so, however, because the earth rotates upon its axis. Such rotation of the earth makes the sun and all the stars appear to rise in the east and set in the west.

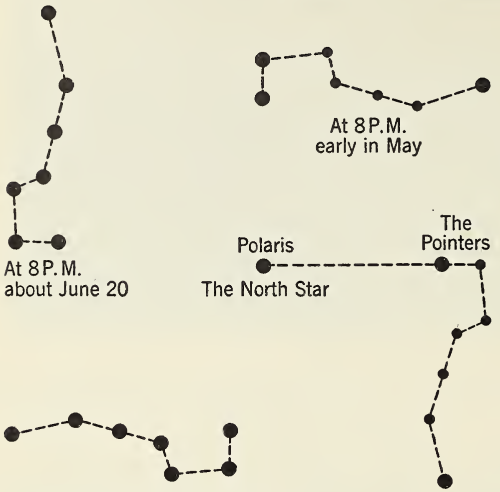



FIG. 2–1. The Pointers of the Big Dipper always point almost directly toward the North Star, no matter what the position of the Big Dipper is. In fact, the Big Dipper seems to revolve about a point which nearly coincides with the position of the North Star.

We find, too, the groups of stars which form the constellations Orion and the Big Dog always in the same position with respect to one another, but appearing to rise in the east and to set in the west. These stars are distant suns, many of them much larger than our sun.

**56. What instruments do astronomers use?** The *astrologers* of the past studied the stars and tried to predict future events from them. They knew much about the constellations and where to find them at any particular time. They knew what particular constellation was on the *meridian* at any particular time, whether that time marked some important event or the birth of some great man. But they did not have instruments to use for studying the stars.

Modern astronomers have many instruments which they use to study the stars and other heavenly bodies. We shall mention only two of them.

*a*) *The telescope.* There are two types of telescopes used by astronomers. One has a large curved mirror. It gathers together a large amount of light from distant stars or planets and reflects it back so it may be brought to a focus and form a small but exceedingly bright image of those stars or planets.

Then a combination of lenses, called an *eyepiece,* is used to magnify that image so it can be studied to better advantage than with the naked eye. The Mount Wilson reflector has a mirror which is 100 inches in diameter. Telescopes are often used for taking photographs of heavenly bodies. Astronomers learn much by studying such photographs. In 1939 glass was poured for a new 200-inch reflecting mirror for a telescope to be mounted on Mount Palomar, California. In 1942 this piece of glass was being ground and polished and was almost ready for use.

In the other type of telescope, a huge *convex* lens (a lens curved like the bottom of a saucer) focuses the rays of light from a distant object and forms a bright image. In the great Yerkes telescope, a lens more than 40 inches in diameter is used. An eyepiece is used to enlarge the image in this telescope too. [See Fig. 2–2.]

*b*) *The spectroscope.* You have no doubt noticed that rays of sunlight which pass through a glass prism form a rainbow-colored band upon a white wall or sheet of paper.

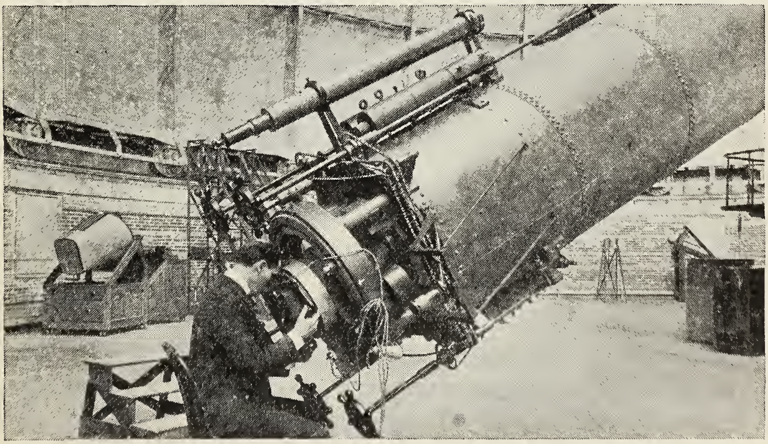


Fig. 2–2. The Yerkes refracting telescope has a lens which is forty inches in diameter. The telescope is mounted on an adjustable floor of the observatory. (*Courtesy Yerkes Observatory*)

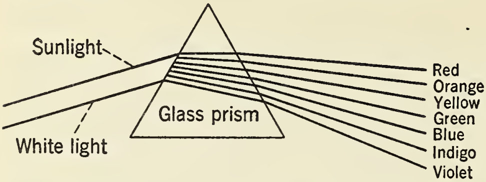
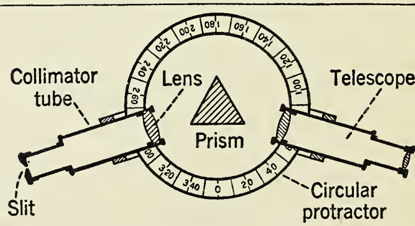



FIG. 2–3. Sunlight is composed of seven different colors. They are sometimes called the rainbow colors.

[See Fig. 2–3.] Such a band of colors is called a *spectrum.* We call it a *solar spectrum* because it is produced by sunlight. *Sol* is the Latin word for *sun.* In the early part of the nineteenth century it was observed by two scientists named Wollaston and Fraunhofer that there are a large number of dark lines in the spectrum produced by the sun. Such lines are found to be in exactly the same position as those which can be produced by burning various elements found on the earth. By comparing the lines produced by the stars with those caused by certain elements, astronomers can tell what the stars are made of. It has been learned that such elements as oxygen, iron, sodium, hydrogen, and dozens of others are present in the sun. By examining the spectra formed by various stars, astronomers can tell that the stars are composed of the same elements that are found on the earth.

By the use of the *spectroscope* and other instruments, astronomers can tell the composition of heavenly bodies, the

FIG. 2–4. A small telescope is used to observe the spectral colors formed by the prism.




size of the stars, their distances from the earth, their densities, their temperatures, and whether they are moving toward the earth or receding from it. [See Fig. 2–4.]

**57. How big are the stars?** There are millions and millions of stars. Many of them are much larger than our sun. A few years ago, Dr. Michelson, then professor of physics at

the University of Chicago, measured the diameter of the bright star Betelgeuse (bē′t'l·jo͝oz), which is in the constellation Orion. He found its diameter to be about 235,000,000 miles. If this star were placed where our sun now is, it would not only fill all the space occupied by our sun, but it would include the present orbit of the earth and it would also extend to some distance out beyond the orbit of the earth. Some other stars are known to be even larger than Betelgeuse.

Some of the stars are so very dense that one cubic inch of their material weighs a ton. Some of them have so low a density that the best vacuum we can produce in the laboratory has a greater density. We know that our sun has a family of planets, but no one knows whether any other star has such a family.

**58. How far away are the stars?** In your study of the planets, perhaps you strained your imagination to the breaking point. Did it not seem almost impossible to think of Pluto as being nearly four billion miles away? In studying the planets, we used the distance from the earth to the sun, 93,000,000 miles, as our yardstick. For example, we spoke of Jupiter as being five times that distance, and of Uranus as being nineteen times that far away. But the distance of the farthest planet from the sun is small when compared with the distance from the earth to the nearest " fixed " star — if we except our sun.

The yardstick used by astronomers for measuring the distances of the stars is the *light-year*. That is defined as the distance which light will travel in one year. The most accurate measurements that have ever been made show that light travels 186,270 miles per second. To find out how far it will travel in one year, we must multiply that number by 60 x 60 x 24 x 365¼. The product of 186,270 x 60 x 60 x 24 x 365¼ is equal to 5.88 million million miles. How much is a million? You will get a good idea if you calculate that it would take you almost six weeks to count even $1,000,000 in one-dollar bills, if you work six days per week, eight hours

each day, and count at the rate of one dollar every second.

It takes light only about eight and one-quarter minutes to travel from the sun to the earth, and it takes light from Pluto only six hours to reach the earth, but the star nearest our sun is so far away that it takes more than *four years* for light from that star to reach us, traveling day and night, at the speed of more than 186,000 miles every second.

The star Arcturus is 40 light-years from our earth. A world's fair was held in Chicago in the year 1893. The Century of Progress Exposition was held in Chicago in 1933, just 40 years after the first world's fair held in that city. The light which was leaving Arcturus in 1893 was just arriving in Chicago in 1933, after a 40 years' journey. It seemed very fitting to use that light to operate the mechanism which was used to open the Exposition in Chicago.

Let us use a different illustration. If an observer on the star Arcturus had a telescope powerful enough to see events occurring on the earth, in the year 1938 he would have been observing things that happened during the Spanish-American War in Cuba in 1898.

The star Betelguese is 270 light-years from us, and some others are estimated to be thousands of light-years away. The nebula in the constellation Andromeda is believed to be at least 800,000 light-years distant, and possibly it is even a million light-years away.

**59. What is the Milky Way?** No doubt you have noticed the broad band of light which can be seen on a clear night in late summer or early autumn, when the moon is not shining. That girdle around the heavens is known as the Milky Way. A branch of the Milky Way also extends overhead in midwinter. [See Fig. 2–5.] By the aid of the telescope, the Milky Way is found to be composed of millions of stars, or suns, apparently so close together that they cannot be distinguished by the unaided eye. The large telescope at Mount Wilson Observatory reveals more than a billion stars in this *galaxy*, of which our sun and solar system are a part.

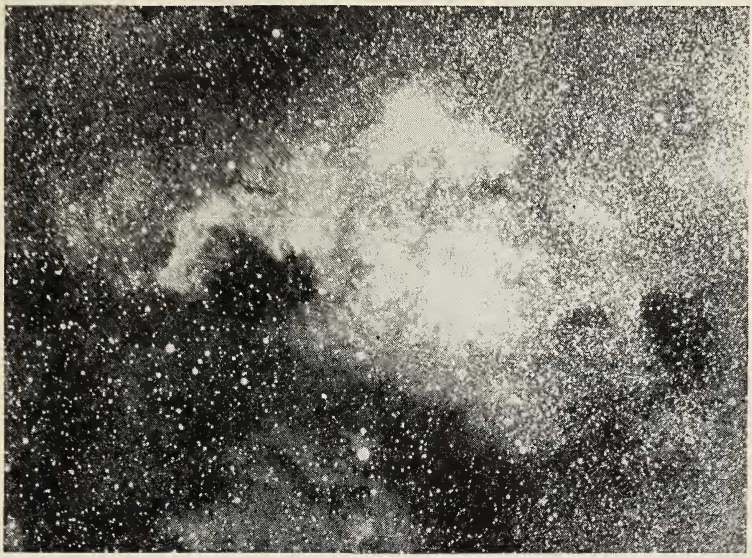


FIG. 2–5. This huge nebula is known as the North American Nebula. The Milky Way is made up of star clusters and cloudlike masses like this. (*Courtesy Yerkes Observatory*)

Our galaxy is an enormous disc-shaped group of stars, all in harmony with the laws of gravitation, and all moving to some extent. Our star cluster is at least 15,000 light-years in thickness, and some 100,000 light-years in diameter. Its shape has at times been compared to that of a watch. In reality the stars are not closely crowded, or even near together. They merely appear that way because they are so far distant. The stars are not really *fixed*, either, but they do move in an orderly arrangement. Our sun, for example, and our entire solar system with it, are moving toward the constellation Hercules at a speed of about 12 miles per second. Why do we speak of the stars as being *fixed?* The distances between the suns of the galaxy are so great, and the motions of the suns themselves are so slow, relatively, that if a person lived to be as old as Methuselah, he would not be likely to see any differences in the position or appearance of the suns in the sky during his lifetime.

**60. Are there other galaxies?** Our star cluster, which is sometimes called the Milky Way, is not the only galaxy in the heavens. Far beyond it, there are a large number of other galaxies, visible to us only as patches of light called *nebulae.* Such nebulae probably contain millions of suns. It is even possible that some of the distant galaxies are larger than our own. The distant galaxies have sometimes been called "island universes." As we study the bigness of the universe, must we not come to the conclusion that "you in your corner, and I in mine" are really not so important as we sometimes like to feel that we are? Perhaps you are beginning to realize the enormous size of the universe of which we and the earth are but a tiny part.

**61. What are some landmarks in the sky?** A group of stars which appear to form a rather definite shape is, as you know, called a *constellation.* Several of the constellations are well known to persons of common education. Some constellations are noted for their remarkable shape. Others are well marked because a particularly bright star forms a part of the constellation. Every high-school pupil should be familiar with the names of at least a half-dozen constellations, and he should be able to locate them, too. Those mentioned in this chapter are easy to find, and they are easy to remember.

**62. Where is the Big Dipper?** The Big Dipper is really a part of the constellation known as Ursa Major, or the Great Bear. Of the seven fairly bright stars in this constellation, four of them form the bowl of the Dipper, and three others form the bent handle. [See Fig. 2–1.] The rotation of the earth on its axis makes the Dipper appear to revolve around the North Star. No matter, however, in what position we see the Dipper, we note that the two stars which form the outer edge of the bowl of the Dipper always point toward the North Star. These two stars are called the *Pointers.* They make it easy for you to find the North Star at any time. You follow the Pointers above the bowl of the Dipper for a distance about 4.5 times the depth of the Dipper.

63. **How can we find the Little Dipper?** Just as the handle of the Big Dipper forms the tail of Ursa Major, or the Great Bear, so the handle of the Little Dipper forms the tail of the constellation known as Ursa Minor, or the Little Bear. The fairly bright star at the end of the handle of the Little Dipper is called Polaris, or the North Star. At a *latitude* of 90° North, or at the North Pole, the North Star is directly overhead. At the equator, the North Star is in the northern horizon. At a latitude of 40° North, the North Star is just 40° above the horizon. From the angle of elevation of the North Star above his horizon, a person can find his latitude.

The other stars of the Little Dipper are not very bright. Two stars which form one side of the bowl are rather brighter than the others. The handle of the Little Dipper gives one the impression that it was upside down when it was attached to the bowl. The rotation of the earth on its axis makes the Little Dipper appear to turn around the North Star as a point, once in twenty-four hours. [See Fig. 2–6.]

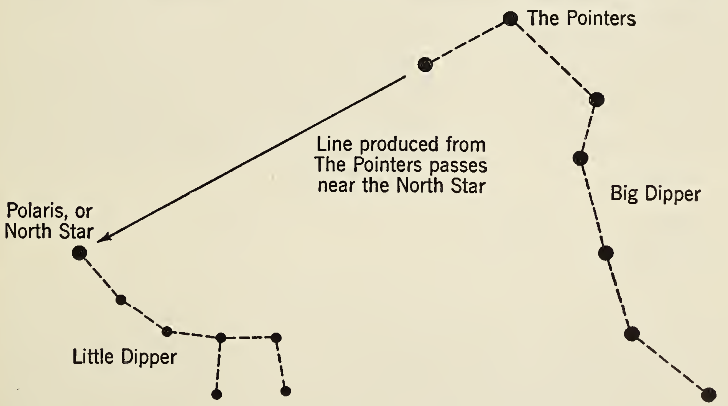



FIG. 2–6. Here is an easy way to find the North Star.

64. **Cassiopeia — the Greek Maiden.** Possibly you have read in Greek mythology the story of the Greek maiden, Cassiopeia (kăs′ĭ·ȯ·pē′yȧ). When she angered the gods, she was punished by being transported, chair and all, to her present

position in the heavens. In order to find this constellation, you may follow a line along the Pointers of the Big Dipper to the North Star, and then continue on beyond that star. On the opposite side of the North Star from the Big Dipper, and about as far distant, you will find the constellation Cassiopeia. Possibly to you this constellation may resemble a Greek maiden seated in a chair, but to most persons it resembles even more a huge letter *W*.

**65. Orion — the Hunter.** In late autumn, one can see Orion, the brightest constellation in the sky, creeping up over the eastern horizon just at sunset. He appears to rise four minutes earlier each day, until in midwinter he stands high up in the heavens in the early evening. To some persons this constellation may look somewhat more like a diamond-shaped tennis racket than like a Greek hero. Two bright stars are supposed to form Orion's shoulders, two others his knees, and a row of three stars forms his belt. [See Fig. 2–7.] Betelgeuse, the star whose diameter was the first to be measured,

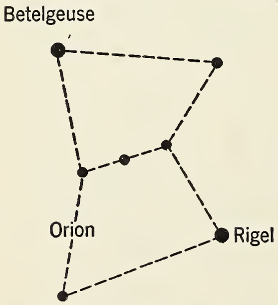



Fig. 2–7. If you do not know the constellation Orion, you should learn to recognize it. Some persons think it the finest constellation. It has two bright stars, Rigel and Betelgeuse.

is a huge red star that forms one of the mighty hunter's shoulders. Rigel, one of the hottest stars known, is a very bright star in one of Orion's knees. Orion is the only constellation which has in it two stars of first *magnitude*.

**66. Pleiades, or the "Seven Sisters."** The Pleiades (plē′-yȧ·dēz) are easily recognized, because they look like a cluster of closely crowded stars. Six stars in this group can be easily counted on a night in winter when the moon is not shining.

A person with particularly keen eyesight can count nine stars. The Pleiades form the shoulder of the constellation Taurus, or the Bull, which the ancients pictured as being chased across the sky by that giant hunter, Orion. In fact, an easy way in which to find the Pleiades is to continue the line of Orion's belt to the westward.

67. **Canis Major — the Great Dog.** It seems only natural that we should find the Great Dog following Orion as he treks westward across the sky in his pursuit of the Bull. You can find the Great Dog by imagining a line extending eastward along Orion's belt. It is easily located, too, from the fact that the brightest star in the entire heavens is found in this constellation. This bright star, which is called Sirius (sĭr′-ĭ·*ŭs*), is only 8.7 light-years from the earth. It is an intensely white star which gives off many times as much light as our sun. Sirius, which is often called the Dog Star, rises at sunset in early winter, and dominates the sky with its brilliance throughout the spring and early summer. A period of about six weeks during late July and August is called the "dog days," because the ancients thought that these days were governed by the Dog Star. Some persons still believe that dogs are more likely to "go mad," or to be attacked by rabies, during the hot sultry dog days, although there is no truth in the belief.

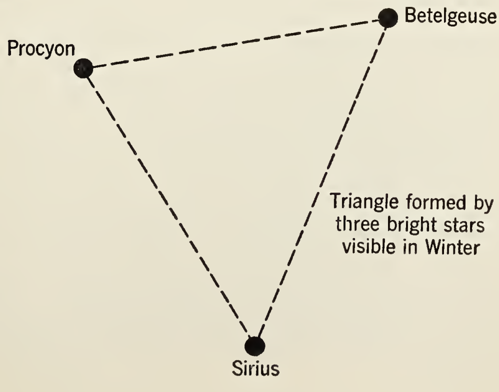



FIG. 2–8. The triangle is made up of three bright stars from three different constellations. It makes an excellent "skymark" for locating those constellations. Procyon is in Canis Minor, Sirius in Canis Major, and Betelgeuse is in Orion.

**68. What are some other constellations?** (*a*) *Canis Minor.* This constellation, which is called "The Little Dog," is not difficult to recognize. It has for its eye the very bright star Procyon (prō′sĭ·ŏn), which forms a huge *equilateral* triangle in the heavens with the Dog Star and Betelgeuse at the other two corners of the triangle. [See Fig. 2–8.]

*b*) *The Sickle.* If you have ever used a sickle to cut grass and are familiar with its shape, you will have no trouble in locating this constellation, which is directly over your head in April. The Sickle forms a part of the constellation Leo, or the Lion. The bright star Regulus forms the end of the handle of the Sickle, and it lies in the paw of the Lion.

*c*) *Gemini.* The constellation Gemini (jĕm′ĭ·nī) is better known as the Twins. It lies to the north and east of Orion, on the opposite side of the Milky Way. It is known by its two bright stars, Castor and Pollux. Castor lies farther north than Pollux, and is not quite so bright. In ancient times, this pair of stars was used by sailors in steering their vessels.

*d*) *Pegasus.* In the early evening during the month of October we find the four fairly bright stars known as Pegasus (pĕg′*ȧ*·s*ŭ*s), or the Winged Horse, almost directly overhead. It is easily identified. Just west of Pegasus is a tiny diamond-shaped group of stars known as Job's Coffin.

**69. What are some of the well-known stars?** In our study of the constellations we have mentioned some of the stars that are conspicuous because of their apparent brightness, or magnitude. As stars decrease in apparent brightness, the number of their magnitude increases. A sixth-magnitude star, for example, is just visible to the naked eye. Sirius, the brightest star of all, is listed as minus 1.6 magnitude. It is even brighter than a star of first magnitude or one of zero magnitude. Vega is a bright blue star of about zero magnitude. You can find it on a line perpendicular to a line drawn from the Big Dipper to Cassiopeia. There are about a dozen stars of first magnitude that are visible at a latitude of 40° North.

Arcturus, an orange-red star in the constellation Boötes (bō·ō′tēz), has already been mentioned. You can find it by extending the line of stars which form the handle of the Big Dipper. Polaris, the pole star, has also been mentioned. Betelgeuse, in Orion, and Antares (ăn·târ′ēz), in the Scorpion, are bright red stars. Pollux is an orange-colored star. Capella, a yellow star in Auriga, is one of our brightest stars.

## *Questions*

1. Why do we not see stars in the daytime? Under what conditions can stars be seen in the daytime?
2. Mention five constellations that you can identify. Tell how you find them. Make a sketch to show the appearance of each of three of them.
3. What is a galaxy? Give a common name for one galaxy.
4. How long does it take for light to reach us from the sun?
5. What is the meaning of the term *light-year*?
6. Why is the distance of stars from the earth measured in light-years?
7. Does the expression *fixed star* mean that the star does not move at all?
8. When we speak of a planet as a wanderer, do we mean that the planet does not follow a well-defined orbit? If not, what does it mean?

## *Some things for you to do*

1. You will find star maps printed in the *Scientific American* each month. Learn how to use such maps. You may find it an interesting hobby to learn some constellations not mentioned in this chapter.
2. Find out what the following terms mean: nova, double stars, and variable stars.
3. Refer to a Nautical Almanac to learn when the North Star is on the meridian. See whether you can then use the North Star to fix a north-and-south line.

## *Think about these!*

1. Why do seasons change on the earth?

2. Have you ever seen the letters *O.S.* (old style) after dates? What do they mean?

3. Which has the greater influence upon the tides, the sun or the moon?

4. Why do we have time belts in the United States?

## *Words for this chapter*

**Uranium** (ū·rā′nĭ·*ŭ*m). An element that has the properties of a metal.

**Radium.** An element discovered by Madame Curie.

**Plane.** As used here, an imaginary flat surface, which touches every part of the earth's orbit.

**Waxes.** Increases, grows larger.

**Gibbous** (gĭb′*ŭ*s). Swelling out.

**Waning** (wān′ĭng). Growing smaller; decreasing.

**Umbra.** A total or complete shadow.

**Penumbra** (pė-nŭm′br*ȧ*). A partial shadow. A place from which part of the light has been cut off.

**Neap** (nēp). Tides produced when the moon is at first or at third quarter.

CHAPTER 3 ______ UNIT 1

# Why Should We Study the Earth as the Planet on Which We Live?

**70. Is our earth a planet?** The earth is one of the family of planets, but we sometimes forget that fact, probably because it is the planet on which we live. If we lived on the planet Mars, then the earth would seem to us there like another planet, just as Venus appears to us now in our own sky. As we travel from place to place, across the ocean or across a continent, the earth seems very large, but when we compare it to the rest of the solar system, it appears to shrink and become rather small. If we compare it with the universe, with its suns and galaxies, it is a mere speck. But the earth is our home, and there is much for us to learn about it.

**71. How big is the earth?** The earth rotates upon an imaginary axis which is 7,899 miles in length. In other words, the earth's diameter, measured from the North Pole to the South Pole, is 7,899 miles. The equatorial diameter is 26½ miles longer than the polar diameter. It is almost 25,000 miles around the circumference of the earth at the equator.

FIG. 3–1. The Grand Canyon of the Yellowstone River is one of the beautiful spots in Yellowstone National Park. (*Courtesy U. S. Geological Survey — Department of the Interior*)

72. **How old is the earth?** No one can answer that question very accurately. Judging from the time it must have taken running water to cut into the earth such gorges as the Yellowstone, Niagara, and the Grand Canyon, the earth must be very old. The age has been estimated, too, by the rate at which *uranium* changes to *radium*, and radium to lead. Radium, for example, loses about one-half its activity in the first 1700 years, one-half of what remains in the next 1700 years, and so on. By using various methods of estimating the age of the earth, scientists conclude that it may be about two billions years old. [See Fig. 3–1.]

73. **What two motions has the earth?** (*a*) *A motion of rotation.* Once in 24 hours, or a trifle less, the earth rotates on its axis. The ends of the earth's axis are called the poles. Since the earth spins on its axis from west to east, that makes the sun appear to rise in the east and to set in the west.

Since the earth has a circumference of about 25,000 miles, then it follows that a person living at the equator is actually traveling more than 1000 miles per hour as he is carried

around upon the surface of the earth. Can you think of a reason why the person is not conscious that he is traveling so far and so fast?

b) *A motion of revolution.* In a trifle more than 365 days, the earth makes a complete revolution around the sun. The path through which it travels is called the earth's orbit, which is not a true circle, but a slightly flattened circle, or an ellipse. The sun is located at one of the foci of that ellipse. Hence we are farther from the sun at some times than we are at other times. Strange as it may seem, we are about 3,000,000 miles nearer the sun in January than we are in July. In January we are about 91½ million miles from the sun, but we are about 94½ million miles distant in July.

As the earth moves around the sun, it must travel almost 600,000,000 miles in one year. That means about 1,600,000 miles each day, about 68,000 miles per hour, or more than 1100 miles per minute. We are not conscious of such great speed, because the air and the water are all carried along with the earth as it moves.

Let us suppose that there is a thin tissue stretched across the earth's orbit. The earth's axis is not perpendicular to such a *plane,* but it is inclined, or tilted, 23½ degrees from the perpendicular to that plane. The axis of the earth makes an angle of 66½° with the plane of the earth's orbit.

**74. Why do we have day and night?** On a table we may place an electric lamp with a concave reflector (a reflector which is hollowed like a cave). That will serve as the sun. At the opposite end of the table let us place a globe from six inches to one foot in diameter. That globe will represent the earth. The room should now be darkened. We see at once that about half the globe is lighted at one time. That part of the globe which is turned away from the light (sun) is in darkness (night). [See Fig. 3–2.]

If we turn the globe slowly on its axis from west to east, we find that new portions are illuminated in turn. If possible, let us turn the globe just one twenty-fourth of the way

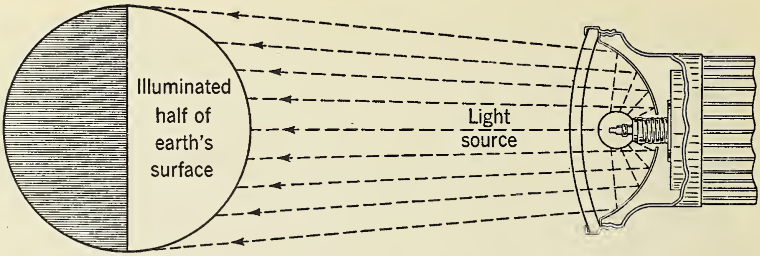



FIG. 3–2. The sun illuminates only a trifle more than half the earth's surface at any one time.

around, or through 15°, since there are 360° in every circle. As we turn the globe one twenty-fourth of the way around, then 15° of the eastern area which had been receiving light (or having day) passes on into darkness. In the meantime, 15° of the western area which had been in darkness (or having night) now moves on into the light. As the sun is setting upon one place, another place on the opposite side of the globe is just having sunrise.

**75. Why do we have a change of seasons?** Let us place a bright, unshaded lamp on the center of a table in a darkened room. That lamp represents the sun. Let us use the top of the table to represent the plane of the earth's orbit. We may use the same globe that we used in section 74 to represent the earth. If we hold the axis of the globe perpendicular to the table top (the plane of the earth's orbit) and then carry the globe entirely around the table, we find that those rays of light coming directly from the sun shine on the equator at all times during the circuit. The slanting rays of light reach as far on either side of the equator as the poles. There is no change of seasons. [See Fig. 3–3.]

If we repeat the experiment, but hold the axis so that it will be inclined 23½° from the perpendicular to the earth's orbit, then we find that at some times the direct rays of the sun shine on the equator and at other times they may be as much as 23½° either north of the equator or south of it. Thus we see that the fact that the earth's axis is inclined 23½° to the

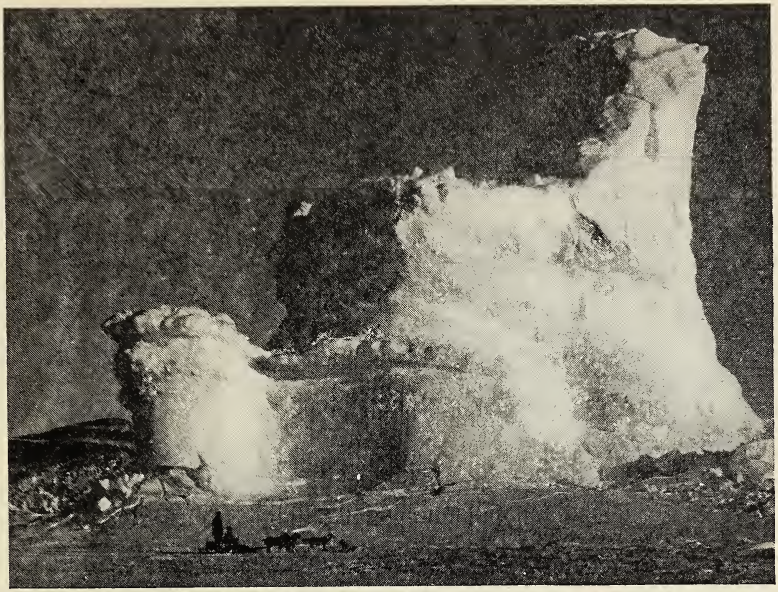


FIG. 3–3. If there were no change in seasons, would great icebergs like this ever melt? How would the polar regions be affected? Would the heat at the equator be changed? (*Ponting from Monkmeyer*)

perpendicular is one of the causes for the change of seasons. This will be demonstrated later on.

If we keep the globe representing the earth stationary at one end of the table, with its axis inclined 23½° from the perpendicular to the earth's orbit, we cannot have any change of seasons. The revolution of the earth around the sun is another one of the causes for the change of seasons.

If we use the globe and lamp to illustrate the change of seasons, we must be careful to see that the axis always points in the same direction. The axis of the earth, for example, always points toward the North Star, no matter where the earth is in its orbit. If we are to have four seasons in regular order, the axis of the earth must not wobble. The imaginary line which represents the position of the earth's axis is exactly parallel to that line which will represent the position of the

axis tomorrow, the day following that, the same day next week, or any other day of the year.

**76. The northern spring.** Let us use the lamp, table, and globe in the same manner as before. Suppose you hold the globe at the west end of the table, with its axis inclined 23½°, and pointed toward the north wall of the room. The *direct* rays of the lamp which represents the sun will then shine on the equator, and the *slanting* rays will reach from pole to pole. [See Fig. 3–4.] When our earth is in this position, about March 21, it is spring in the northern hemisphere and autumn in the southern hemisphere. This position is called our *Vernal Equinox.* The days and nights are of equal length.

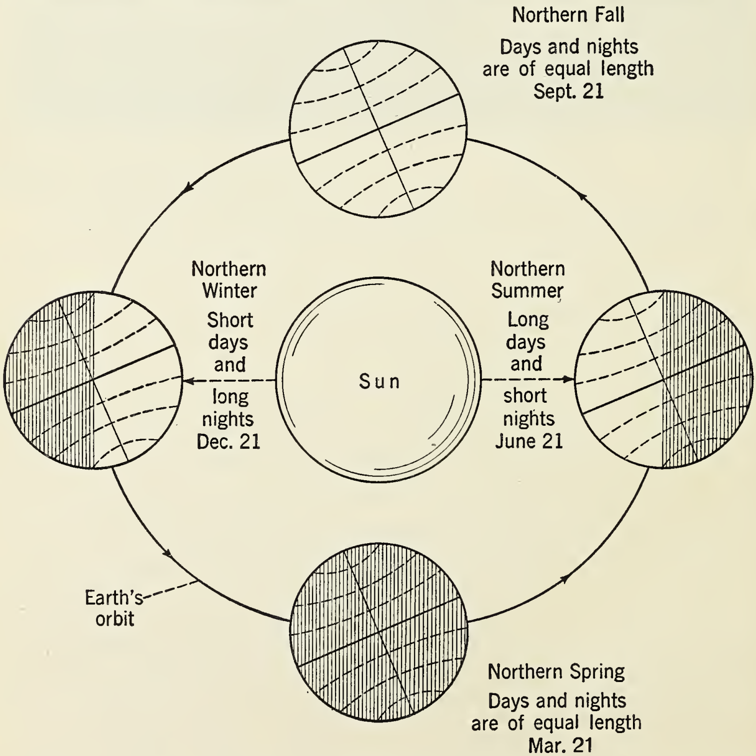



FIG. 3–4. The revolution of the earth around the sun is one of the causes of the changes of seasons. Can you give another cause?

We now move the globe on toward the south side of the table, just as the earth moves on around the sun. As we move, we must be careful to keep the axis always pointed in the same direction, toward the north wall of the room, just as the earth's axis points toward the North Star. As you advance, the North Polar region gradually faces more toward the sun.

77. The northern summer. With our table, lamp, and globe, let us see what the conditions will be three months after we started on our journey around the sun. The date is about June 21. It is summer in the northern hemisphere and winter in the southern hemisphere. *Why?* With the North Pole turned 23½° toward the sun, and the South Pole turned 23½° from the sun, we find that the sun's *direct* rays are now shining on the Tropic of Cancer. Its slanting rays extend 23½° beyond the North Pole, but they lack 23½° of reaching the South Pole. [See Fig. 3–5.] We have long, hot days and

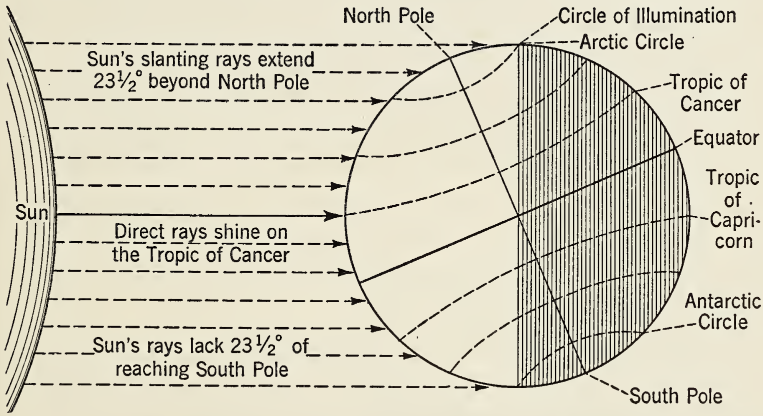



Fig. 3–5. This diagram shows how the earth is heated and lighted during our northern summer.

shorts nights in the northern hemisphere. In New York City the longest day in summer is slightly more than 15 hours from sunrise to sunset, and the twilight adds to that a couple of hours more of daylight. Let us move another three months, pausing at the eastern end of the table for observations.

**78. The northern autumn.** If you have been careful to keep the axis pointing always toward the North Star, you will find that in the earth's new position, neither pole is now turned toward the sun. The vertical rays again shine directly upon the equator, and the slanting rays reach from pole to pole. The days and nights are equal at all places on the earth. The date is about September 21, the date of the *Autumnal Equinox.* The southern hemisphere is now having its spring. As we continue our journey for another three months, we notice that the North Pole is now being turned more and more away from the sun.

**79. The northern winter.** We pause for observations when we reach the north side of the table. We find that the South Pole is now turned 23½° toward the sun and the North Pole 23½° from the sun. The *direct* rays of the sun shine on the Tropic of Capricorn, and the *slanting* rays shine 23½° past the South Pole, but they lack 23½° of reaching the North Pole. The time is about December 21, and it is winter in the northern hemisphere. The days are short and the nights are long and cold. In New York City it is almost 15 hours from sunset to sunrise; at the Arctic Circle the night may be twenty-four hours long; and at the North Pole it is six months in length. In another three months we are back to the place from which we started. In an exactly similar manner, the earth continues its journey in its orbit around the sun, season following season in regular order.

**80. Why do the days and nights vary in length?** It may be well to repeat the experiments of the preceding sections, and pay especial attention to that portion of the globe which is lighted in each position. At the times of the equinoxes, the days and nights are almost equal. They are not quite equal, because the diameter of the sun is so much greater than that of the earth that it always illuminates a little more than half of the earth's surface at one time.

When you hold the globe in the position used for the northern summer, you see that slightly more than half the globe is

illuminated, but now, when the North Pole is turned toward the sun, the illuminated portion includes more of the northern hemisphere and less of the southern hemisphere. The opposite is true during the northern winter. The real reason why the days and nights are of unequal length in summer and winter is that the earth's axis is inclined 23½° from the perpendicular to the plane of the earth's orbit. You will remember, too, that this is also an *important* cause of the change of seasons.

**81. Why is it hotter in summer than in winter?** Many persons have the mistaken idea that the earth is nearer the sun in summer than it is in winter, and that we receive more heat from the sun for that reason. But as a matter of fact, *we are actually 3,000,000 miles nearer the sun in January than we are in July.*

We receive more heat in summer because at that time the sun's rays are more *direct,* or *less slanting.* On June 21, the direct rays of the sun are shining on the Tropic of Cancer, about 1600 miles north of the equator, and the slanting rays received by one who lives as far north as New York are *much more nearly vertical* than those which he receives in January when the winter sun is well down toward the southern horizon, even at noontime.

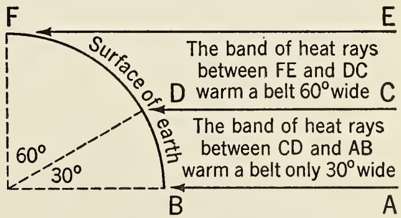



FIG. 3–6. The more direct the rays of the sun, the more heat and light are received. Slanting rays furnish little heat or light.

Let us refer to Figure 3–6 to see why the *direct* rays of the sun give more light and heat than the *slanting* rays. The curving line represents the curved surface of the earth. The sun is so far from the earth that we may consider the rays of light coming from it as parallel rays. The number of heat rays between the lines AB and CD is the same as the number

between the lines CD and EF. But you will notice that the heat rays between AB and CD are concentrated on a much smaller area of the earth's surface than are those between CD and EF. Possibly there are twice as many square miles of surface to be warmed between D and F as there are between B and D. If that is so, then each square mile under the slanting rays will receive just half as much heat as a square mile under the more direct rays.

You may make the following demonstration to show how light rays spread out over a larger surface when they are slanting than they do when they are direct. Take a flashlight and hold it first at right angles to a wall. Then hold it so that the light rays will be slanting. Compare the areas of the two spots and also notice which spot of light is the brighter. Heat rays behave in the same manner as light rays, but we cannot see them.

There is still another reason why slanting rays are not so warm as direct rays. Our atmosphere absorbs some of the heat rays. If you refer to Figure 3–7, the heavy arc repre-

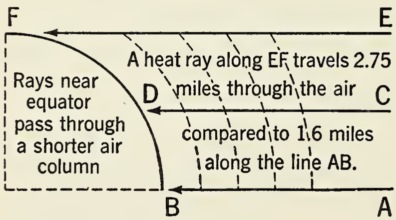



FIG. 3–7. The slanting rays of the sun pass through deeper layers of air than direct rays do. More of the slanting rays are absorbed by the atmosphere.

sents the earth's surface; the dotted arcs the atmosphere. You notice that the rays of heat falling upon the earth at F have traveled through a deeper layer of air than those rays which fall upon the earth at either D or B. The first layer has a depth equal to the line EF, the second one equal to the length DC, and the third to the length BA.

To summarize, then, we receive more heat in summer than we do in winter for three reasons: (a) The *direct* rays from the sun are not spread out over so much of the earth's surface

as are the *slanting* rays; they are more intense. (*b*) The direct rays travel through a shorter air path than the slanting rays do, and less heat is absorbed by the air itself. In Figure 3–8, the pupil can see how very slanting the sun's rays are in winter when the northern hemisphere is turned away from the sun. (*c*) The days are much longer than the nights.

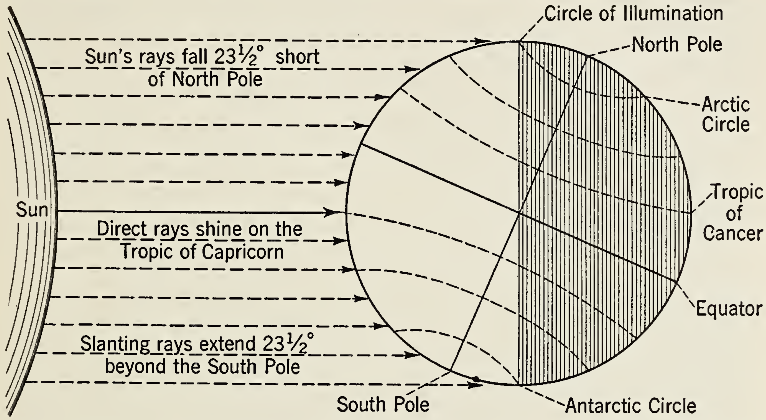



FIG. 3–8. This diagram shows how the earth is heated and lighted during our northern winter. It is summer in the southern hemisphere.

**82. The moon.** The moon, admired alike by poets and lovers, is the only known satellite of our earth. It revolves around the earth in much the same manner in which the earth revolves around the sun. The moon seems to be made up of the same elements as those that compose the earth, and that is not strange, because it is believed that the moon was a part of the same nebulous mass as the earth.

The surface markings of the full moon are interesting, and one can make them form almost any picture, depending entirely upon his imagination. You may see a man in the moon; someone else may see a woman; and a third person may see some other animals or figures. But let us look at the moon through a telescope. Then we see that the surface markings really consist of mountain ranges and valleys, with here and there a huge crater like that of a volcano. [See Fig. 3–9.]

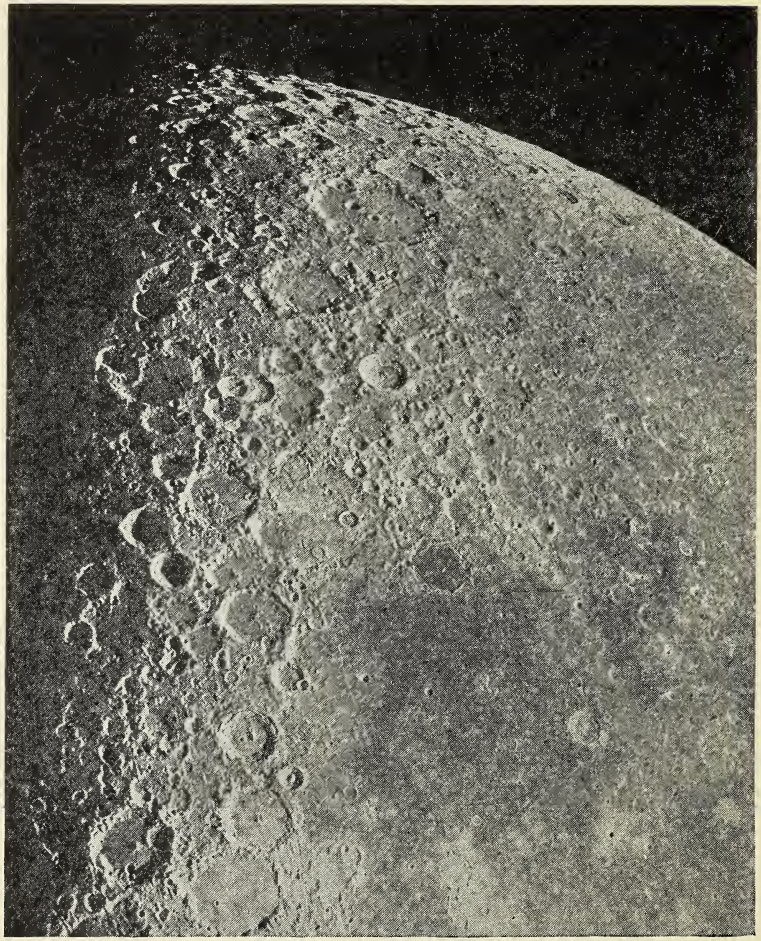


FIG. 3–9. Bleak and cold as this lunar region looks, with its mountains and craters, it is part of the same moon from which the earth gets its moonlight. The photograph was taken by means of a telescope, when the moon was at the last quarter. The region shown is the lower portion of the moon. (*Courtesy Mount Wilson Observatory*)

When measured by the length of their shadows, the mountains of the moon are found to be as high as those of the earth.

83. **What do we know about the moon?** We see but one face of the moon, because the moon rotates on its axis in just the same length of time that it needs to revolve around the earth. Now that your curiosity is aroused, you are probably like the rest of us in feeling that you would like to see how the far side of the moon looks. But you cannot see the far side of the moon, if it always keeps its face turned toward you. If you walk in a circle around a person, *keeping your face turned toward the person all the time,* you will find that you have turned exactly once around by the time you have completed one revolution. But the person will have seen your face, not the back of your head.

The time required for the moon to make one revolution around the earth, or the time from one new moon to the next, is 29½ days. This is our *lunar* month, which is a little shorter than the *calendar* month. As a rule the moon rises 52 minutes later each successive night with some variations.

The moon has a diameter of 2163 miles, and its average distance from the earth is 240,000 miles. It is our nearest neighbor. Its distance varies, however, because its orbit is not a true circle, but an ellipse. At *perigee* (pĕr′ĭ·jē), when the moon is nearest to the earth, it is about 30,000 miles closer to the earth than at *apogee* (ăp′ō·jē), when it is most distant. When the moon is at apogee, eclipses are less likely to occur.

The plane of the moon's orbit makes an angle of about 8° with the plane of the earth's orbit. There are two places, then, at which the moon cuts across the earth's orbit each lunar month. Those places are called *nodes.* If the moon happens to be near a node at full moon, there may be an eclipse of the moon. If it happens to be near a node at new moon, then an eclipse of the sun is likely to occur. The eclipse is more probable, and it is more likely to be a total eclipse, if the moon is at perigee when it crosses the nodes. [See Fig. 3–10.]

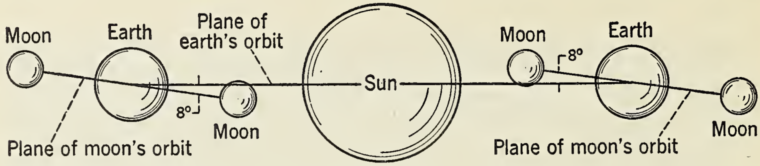



FIG. 3–10. Eclipses occur when the moon is near a node at either full moon or new moon.

It is not believed that the moon has an atmosphere. If it does, it is exceedingly rare. The moon does not give off any light of its own, but reflects the light it receives from the sun, just as a huge mirror would do if it were hung in the sky in the moon's place. It is estimated that it would take more than 600,000 full moons to give us as much light as the sun does.

**84. What are the phases of the moon?** Strictly speaking, we never see the *new* moon, because it sets with the sun. The following night, when the moon sets about 52 minutes later, we see a thin arc of light, crescent-shaped; this phase is commonly called the new moon. As we watch from night to night, the crescent broadens, until, at the end of one week, we see one-half of that face of the moon which is turned toward the earth. *This phase of the moon is called the first quarter.*

Then the moon *waxes* rapidly, through the *gibbous phase,* until it becomes *full moon,* at the end of two weeks. Just as the sun is setting in the west, we see the full moon rising in the east. At full moon we can see all of that face of the moon which is turned toward the earth, because that face is also turned toward the sun and thus is completely lighted. The full moon shines all night long.

During the next two weeks we have a *waning* moon. It first passes through the gibbous phase of what is called the old moon. At the end of a week, only one-half of the moon's face is illuminated and visible. This phase is called the third quarter, or last quarter. The lighted part of the moon now

seems to diminish rapidly during the fourth week as it passes through the crescent (old) phase. Two weeks after full moon, we have new moon again. Then the phases begin again anew.

**85. Why does the moon have phases?** It will help us to explain the phases of the moon if we draw a diagram like that shown in Figure 3–11. The large outer circle represents the

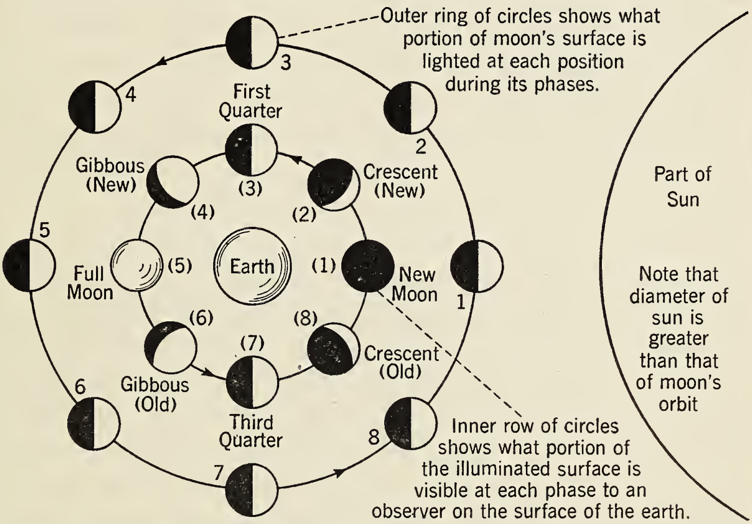



FIG. 3–11. The outer row of circles shows the part of the moon which is lighted by the sun. The inner row of circles shows the part of the lighted portion which one can see from the earth.

moon's orbit. Upon it we have eight small circles which represent the moon at different positions in its orbit, as we would expect to find it at intervals of about 3½ days. The sun, which is greater in diameter than the entire orbit of the moon, is at the right. The white portions of the eight small circles show that a trifle more than one-half of the moon's surface is illuminated by the sun. The circle in the center is the earth.

The next question that arises is how much of the illuminated half of the moon will an observer on the earth see at each of the phases of the moon. To show that, we draw a middle

circle and place upon it eight small circles to correspond to the positions of the moon at the 3½-day intervals. If you are on the earth, how much light do you think you will see from the new moon? Since all the lighted part is turned away from you, of course you will not see any. Hence, we make the circle 1 entirely dark. In the same manner we *shade* each of the small circles in the middle row to make them appear just as an observer on the earth would see them. He sees all the lighted portion at full moon. Hence that circle is not shaded at all. At first and third quarters, the moon is at right angles to a line from the earth to the sun. In each case we see *one-half of the illuminated half* of the moon, or a *quarter.* Look at circles 3 and 7. When the moon is at the positions shown at 2 and 8, we see only a crescent of light.

86. What is an eclipse? Diogenes (dī·ŏj′ė·nēz) was a Greek philosopher who is said to have lived in a tub and to have taken his exercise by carrying a lantern in daylight about the streets of Athens, "looking for an honest man." The story is told that King Alexander the Great stopped at Diogenes' tub one day and asked, "What favor can I do you?" Diogenes replied, "You can stand out of my sunlight." He objected to being eclipsed by King Alexander. If someone comes between you and your light source, he eclipses you by cutting off your light. That is exactly what happens when the moon, which is an opaque (not transparent) body, comes between you and the sun. The sun is eclipsed for you. In a similar manner, when the earth comes directly between the sun and the moon, the earth's shadow falls upon the moon, and the moon is eclipsed.

An eclipse, then, is merely a shadow, and a shadow is caused when some opaque body cuts off the rays of light that are coming from some luminous body. A luminous body shines of its own light.

You have probably read how a Connecticut Yankee in King Arthur's Court used his knowledge of eclipses to terrorize King Arthur's warriors. Savages and semicivilized tribes are

terrorized by eclipses, particularly by eclipses of the sun, just as a child may be frightened by shadows.

**87. How are eclipses caused?** Let us study Figure 3–12 to see how an eclipse may be produced. The circles S, E, and M represent the sun, earth, and moon respectively. Light

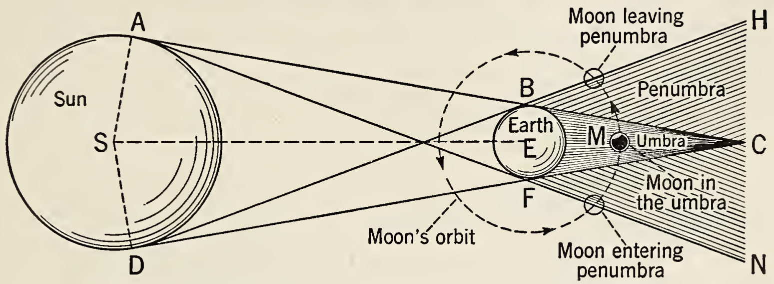



FIG. 3–12. An eclipse of the moon can occur only when the moon is full or nearly so.

from the sun travels in straight lines. It is obvious that the earth, an opaque body, will cut off all the sun's light from that cone-shaped space which is included between BC and FC. A dark shadow, from which all light is excluded, is called an *umbra*. As the moon, in its revolution around the earth, passes into the earth's umbra, it is totally eclipsed.

The space included between the lines BH and BC, and also that included between FC and FN is in *partial shadow*. Only a part of the sun's rays is cut off from them. Such a partial shadow is called the *penumbra*.

As the moon revolves around the earth at the time of an eclipse, it first enters the earth's penumbra and begins to be darkened. It continues to grow darker and darker as more and more of the light from the sun is cut off by the earth. Then it enters the umbra, and the darkness is at its maximum. An hour or two later the moon leaves the umbra and the darkness grows less and less as it passes through a second portion of the penumbra. Then the moon leaves the penumbra and the eclipse is over.

An eclipse of the moon is *total*, if the entire portion of the

moon passes through the umbra. If only a part of the moon passes through the umbra, then the eclipse is only partial. Of course *an eclipse of the moon can occur only at full moon.*

At the time when the moon is new, it is possible for the moon to come directly between the sun and some portion of the earth's surface. When that happens, there is an eclipse of the sun which is visible to observers from that part of the earth's surface between A and Y. When the moon is at the position shown in Figure 3–13, an eclipse of the sun occurs,

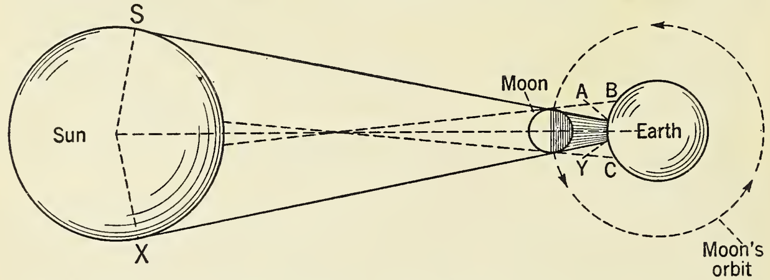



FIG. 3–13. An eclipse of the sun can occur only at new moon or near that time.

which is *total* for an observer on the earth's surface between the limiting lines AS and YX. For an observer at B or at C the eclipse is a *partial* one.

Sometimes the moon may be just far enough away from the earth so that an observer can see a ring of light at the edges of the sun's disc, just as you can see a ring of light if you hold a silver dollar at arm's length between your eye and the sun. This is called an *annular* (from the Latin word *annulus,* a ring) eclipse. The moon is too small ever totally to eclipse the sun except for observers along a narrow path across the earth's surface.

**88. What causes tides?** We know there is a force called gravitation which attracts a body to the earth, and that it attracts all bodies to one another. In fact, the force of gravitation is universal. It is the gravitational pull of the sun and

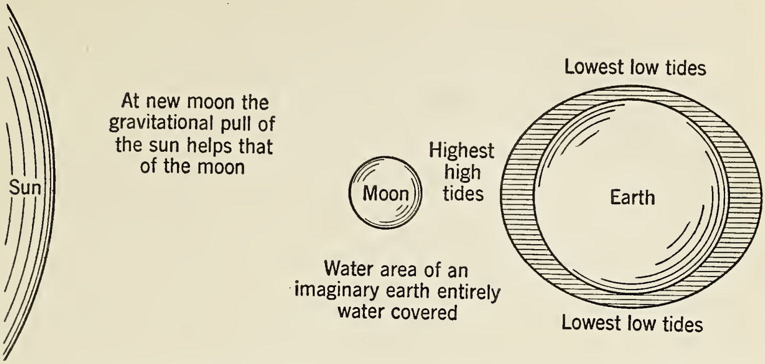



FIG. 3–14. This diagram shows how the gravitational pull of the sun and the moon would affect an earth entirely covered with water. The phase is new moon.

the moon upon the waters of the earth that causes them to bulge out on opposite sides of the earth and form *tides*. [See Fig. 3–14.] The moon is much smaller than the sun, but it is very much nearer. For the latter reason, the moon is a more important factor in producing tides than is the sun.

*High tide,* or *flood tide,* occurs at intervals of about every twelve hours. One high tide each day is produced when the moon is on the same side of the earth as the high tide, and another high tide occurs when the moon is on the opposite side of the earth. Therefore, every place on the seashore has two high tides every day.

The *ebb tide,* or *low tide,* occurs between the high tide intervals. Since the moon rises about 52 minutes later each day, the tidal wave occurs a little less than an hour later on each successive day. The tidal wave which is set up by the moon does not occur when the moon is directly on the meridian, but it always lags behind the moon. The lag of the tide increases near the shore, especially where the water is shallow.

When you are tugging on a rope attached to a sled and someone helps you pull the rope, his force is added to yours. In a similar manner, at new moon both the sun and the moon are on the same side of the earth. Hence, the sun adds its

gravitational pull to that of the moon; hence we have at new moon the highest high tides and the lowest low tides that it is possible to have. We have *high* flood tides and *low* ebb tides at full moon, too. At full moon, the sun is on the opposite side of the earth from the moon, and they pull in opposite directions. Hence the water bulges up to form high tides on opposite sides of the earth. The tides that occur at new moon and at full moon are called *spring* tides.

At the first quarter and at the last quarter, the sun and moon pull at right angles to one another. See Figure 3–15 to verify

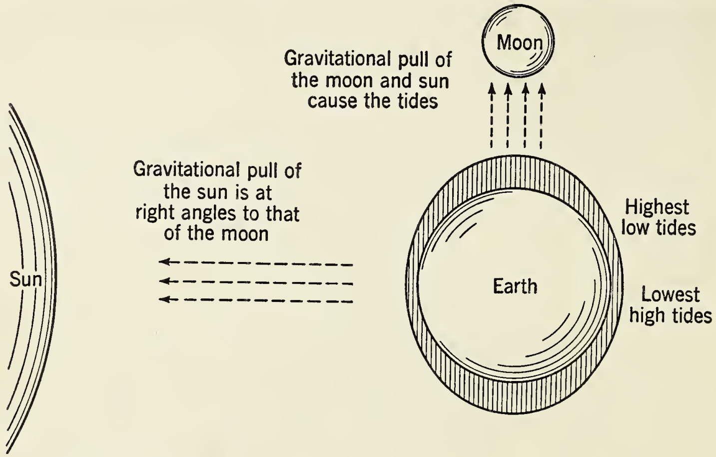



FIG. 3–15. When the moon is at either first quarter or third quarter, the sun and moon pull at right angles to each other in the formation of tides.

the positions of each one. The sun and moon produce at such times what are called *neap* tides. These tides are not so high as the high tides at new moon and full moon, nor so low as the low tides.

**89. How high are the tides?** Out in the open ocean, the tidal range is not more than one or two feet, but at the shores it varies from three feet to ten feet. In some V-shaped arms of the ocean, such as the Bay of Fundy, the tidal range may vary from thirty feet to fifty feet, or even more. The high

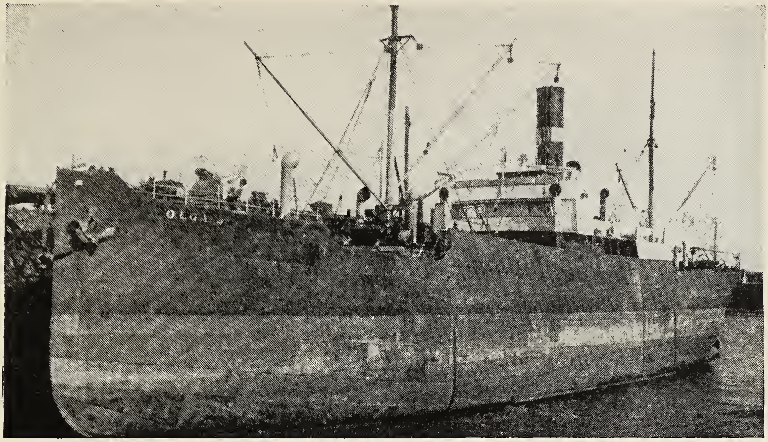


FIG. 3–16. When the tide is low at Saint John, New Brunswick, a large vessel may rest upon the harbor mud. When the tide comes in, the water rises and floats the vessel. (*Courtesy John L. Lochhead*)

tide comes in so rapidly that some land animals may be caught by the rapid rise of the water. [See Fig. 3–16.]

The tides in the Mediterranean Sea are not higher than a few inches. In the Great Lakes they are almost too slight to measure. A *tidal race* may occur when a high tide from the Atlantic Ocean sweeps up a river like the Amazon. This river is several score miles in width at its mouth. When the tide flows up the river, it grows higher and higher as the river becomes narrower. The waters pile up and produce high waves, especially when they meet the river current flowing toward the ocean. Sometimes the wave reaches a height of sixteen feet.

The reversing tides of the Saint John River in New Brunswick, Canada, are interesting. The flood tide flows up the river and seems almost to stop the flow of the river for a short time as the tidal wave and the river struggle for mastery. Then the tide flows upstream, carrying some of the river water with it. When the reversal comes, both tide and river flow downstream with violent rapids. [See Fig. 3–17.]

FIG. 3–17. The reversing tides of the Saint John River in New Brunswick. The waters pile up as the incoming tide meets the water flowing down the river. (*Courtesy John L. Lochhead*)

Long Island Sound is not so deep as the Atlantic Ocean. As the tides come in from the eastern end of the sound, they are retarded more than are the same tides in the Atlantic Ocean south of Long Island. The tides from the ocean flow into New York Bay, through the East River and eastward into Long Island Sound. As they meet the tidal wave which is coming into the sound from the east, they pile upon one another and form what is called a *tidal bore,* or an *eager.* Such a tidal bore may capsize fishing boats and other small vessels.

**90. Of what value are the tides?** The high tides are important in washing the shores and in carrying away refuse. Undoubtedly they bring food to such *fixed* animals as sponges, sea anemones, and oysters. Sometimes they may hinder navigation by carrying a vessel out of its course, but more often they aid navigation. Some harbors are so shallow that vessels can enter or leave only at high tide. Attempts have been made to use the tremendous energy from the unceasing, restless, tidal waves for producing water power. Millions of dollars have been spent on such a project at Passamaquoddy on the coast of Maine. If the demand for water power be-

comes great enough, the project may become a commercial success.

91. **How do you locate places?** If you have always lived on land, this may seem to be a peculiar question. You might answer regarding Cincinnati, for example, that it is a city on the Ohio River in the southwestern part of Ohio. You might locate Syracuse as being about 150 miles west of Albany, and Albany as being about 140 miles north of New York City. But on the ocean the problem is decidedly different.

Try to imagine an earth entirely covered with water. At some place on this water-covered globe there is an ocean vessel. How can you locate it? You will find it quite impossible, unless you draw two sets of *imaginary* lines upon that globe, east and west lines, and north and south lines. You can then locate the vessel by saying that it is so many degrees north or south of one of those imaginary lines, and also so many degrees east or west of one of the north and south lines. Perhaps now you begin to understand why we have *latitude* and *longitude*. [See Fig. 3–18.]

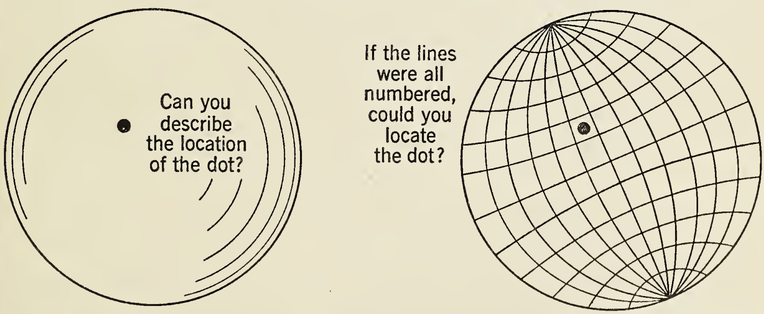



FIG. 3–18. It is almost impossible to describe the location of a point in a circle, or of a ship sailing on an all-water globe. Such a ship can be located by means of parallels and meridians.

92. **What is latitude?** We may use a large black globe about twelve inches in diameter to represent the earth. Suppose it is entirely covered with water and a ship is sinking at the point X. That is the spot you are to locate. In order to

do so, set the globe spinning on an axis, just as the earth spins on its axis. The ends of the axis are *the poles,* and those two points may be marked North Pole and South Pole.

Midway between the two poles we then draw a line all the way around the globe. That line is called the *equator.* Since there are 360° in every circle, the distance from the equator to either pole will be exactly 90°. The equator is made the starting point for measuring latitude, *and its latitude is zero degrees.* Any place north of the equator is in north latitude. Places south of the equator are in south latitude.

We may next proceed to draw between the north pole and the equator as many *parallel* lines as are convenient. They may be 1°, 5°, 10°, 15°, or even farther apart. Suppose on the black globe we draw eight of them, 10° apart. The North Pole is at 90° north latitude. If the X we marked on the globe lies between the parallels 20° and 30°, then it is more than 20° north latitude and less than 30°. Perhaps it is midway between the two. Then its latitude is 25° north. *The latitude of any place on the earth is its angular distance, measured in degrees, north or south of the equator.*

**93. What is longitude?** The twenty-five degree parallel is several thousand miles long, and locating a place as somewhere on that parallel does not give a very exact location. In addition to the parallels, we must have more lines. Let us draw a line from the North Pole straight south through the equator and on to the South Pole. Such a line is called a *meridian.* In a similar manner, we may draw as many meridians from pole to pole as we find convenient. Possibly we prefer to draw them 10° apart. If we find that the spot X on the globe lies between the meridians marked 10° and 15°, we have located it more exactly than we did before, because now we may give its position in relation to two lines.

Where do map makers draw the first meridian? They consider the *prime* (first) *meridian* the one which passes through Greenwich (Grĭn′ĭj), England. All places to the east of

Greenwich, between the prime meridian and the 180th, are in east longitude. Places to the west of Greenwich, between the prime meridian and the 180th, are in west longitude. *Longitude may be defined as the angular distance, measured in degrees, east or west of the prime meridian.*

Suppose that a vessel is at 40° north latitude and 45° west longitude. How do we find it? One could travel northward along the prime meridian from the equator to the 40° parallel. Then he could travel westward along the fortieth parallel to the 45° meridian. The vessel is 40° north of the equator and 45° west of the prime meridian.

**94. How many miles are there in a degree?** The distance around the earth at the equator is 24,899 miles. That distance is also 360° because it is a circle. If we divide 24,899 miles by 360, we find that there are 69.16 miles in one degree of longitude at the equator. But the meridians all meet at the poles. The distance between the meridians at the poles is zero. In another way, too, we find that there can be no longitude at the poles. If you are at the North Pole and wish to leave, in how many directions can you go? Of course there is but one direction in which you can go. That is south. It is impossible to travel either east or west from the North Pole. In traveling in a straight line from any spot on the globe to the North Pole, you must travel north. When you return, you must travel south.

At the fortieth parallel, one degree of longitude is a trifle more than 50 miles in length. At the fiftieth parallel, one degree of longitude is about 43 miles in length, and at the sixtieth parallel it is slightly more than 36 miles in length. At the Arctic Circle, it is less than 30 miles. Thus, you see, the miles represented by a *degree of longitude vary* from zero at the poles to 69.16 miles at the equator.

The distance around the earth measured along a meridian is slightly less than it is around the earth measured along the equator. Hence, a degree of latitude is slightly less than the greatest value for a degree of longitude. Because the earth

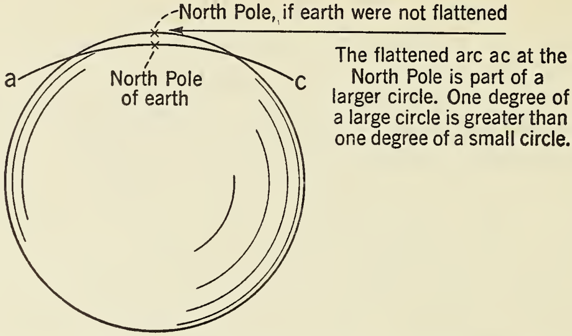



FIG. 3–19. The larger the circle, the greater the value of one degree in that circle.

is flattened at the poles, and the degrees of latitude near the poles are a part of a greater circle, the value of a degree of latitude near either pole may be 69.4 miles. [See Fig. 3–19.]

**95. How is longitude related to time?** When the sun is directly above the prime meridian, it is noon at Greenwich, England, and at all other places on that meridian. It is midnight on the 180th meridian. Twenty-four hours later, the earth will have made a complete rotation on its axis from west to east, and it will then be noon of the following day at Greenwich. In other words, 360° of the earth's longitude whirl beneath the sun every 24 hours. How many degrees will pass beneath the sun in one hour? If we divide 360° by 24, *we find that in one hour of time fifteen degrees of longitude pass beneath the sun.* You may illustrate this fact by focusing a flashlight upon the prime meridian of a globe, and then rotating the globe from west to east. If you turn the globe through one complete rotation in 24 hours, then you will see that the meridian which is 15° west of Greenwich moves eastward 15° in exactly one hour. If it is noon at Greenwich, it is only 11:00 A.M. at any place on that meridian which is 15° west of Greenwich, and it will not be noon there until one hour later, when that meridian will have moved eastward 15°. These examples show *that 15° of longitude correspond to one hour of time.*

The city of Philadelphia is at 75° west longitude. If it is noon at Greenwich, what time is it at Philadelphia? The difference in longitude is 75°. Dividing 75 by 15, we find that the difference in time is 5 hours. The sun will not be on the meridian at Philadelphia for another 5 hours. Hence, the time at Philadelphia is 7:00 A.M.

Berlin, Germany, is nearly 14° east of Greenwich. Hence, the time there is one hour faster than it is at Greenwich, England. In August, 1936, when the Olympic Games were being held in Berlin, persons living in the eastern part of the United States turned on their radios at 12:30 P.M. to hear a radio announcer describe a race being run at 6:30 P.M. in Berlin.

Pasadena, California, lies between the 118° and the 119° meridians. Since New York City is 74° west longitude, the

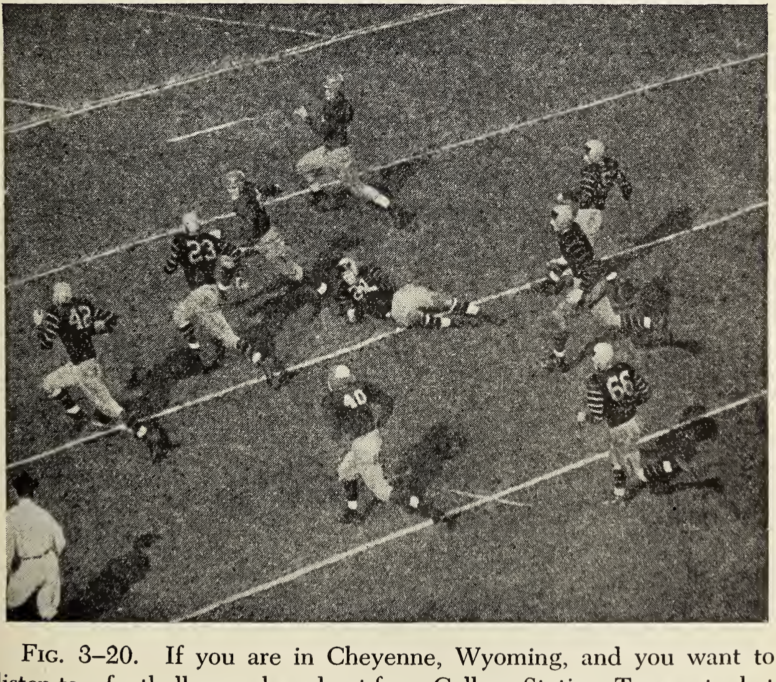


FIG. 3–20. If you are in Cheyenne, Wyoming, and you want to listen to a football game broadcast from College Station, Texas, at what time must you tune in, if the broadcast is to begin when it is two o'clock in College Station?

difference in longitude between them is about 45°. A Rose Bowl football game on New Year's Day is scheduled to start at 2:00 P.M. in Pasadena. At what time must a listener at New York City tune in to hear the opening kick-off announced? [See Fig. 3–20.]

96. Why do we have time belts in the United States? Before there were any railroad trains or automobiles, 50 miles was considered a fairly long day's journey. If George Washington had started from New York and traveled westward toward the Delaware River for 50 miles, he would have covered about one degree of longitude. If his watch was correct when he left New York, it would be 4 minutes fast when he stopped for the night at a point 50 miles west of New York. If 15° of longitude correspond to 60 minutes (one hour) of time, then 1° of longitude corresponds to 4 minutes of time. That 4 minutes' difference in time would probably not have mattered much to our first president.

But let us contrast modern days with colonial times. Now a man travels from Albany to Chicago. The distance between them is about 15°, or about 750 miles. The difference in time is one hour. As the man travels westward by train, he probably covers 50 miles the first hour of his journey. His watch is *four minutes fast.* In another fifteen minutes, his train has probably moved westward another 12.5 miles. His watch is now five minutes too fast. What shall he do? It would be a nuisance to set his watch back one minute for every 12.5 miles he travels westward. By the time he had reached Syracuse, he would have set his watch back about a dozen times in his effort to keep it correct. By the time he reached Buffalo, he would have set his watch back about 24 minutes. To avoid the confusion from so many *local times,* time belts have been established, each differing from the adjoining belt by one full hour of time.

All those places fairly close to the 75th meridian have the same time, Eastern Standard Time. The traveler finds that Albany, Syracuse, Rochester, Buffalo, Cleveland, and Toledo

all have Eastern Standard Time. At Chicago he finds himself in the Central Time Belt, which is governed by the 90th meridian. When the traveler reaches Chicago, or a little before he arrives, *he sets his watch back one full hour.*

Suppose he travels on west from Chicago. He keeps his watch set at Central Time all the way through the Central Time Belt. Denver is on the 105th meridian, and of course the sun rises one hour later in Denver than it does in Chicago. Denver has Mountain Time, which is one hour slower than Central Time, and two hours slower than Eastern Standard Time. Mountain Time is governed by the 105th meridian.

But our traveler is going on to the Pacific Coast. As he leaves Salt Lake City, he sets his watch back another hour, for he is then entering the Pacific Time Belt, which is governed by the 120th meridian. If one is traveling eastward, he sets his watch forward one hour as he leaves Salt Lake City; he sets it ahead again as he leaves Denver; and again when he leaves Chicago.

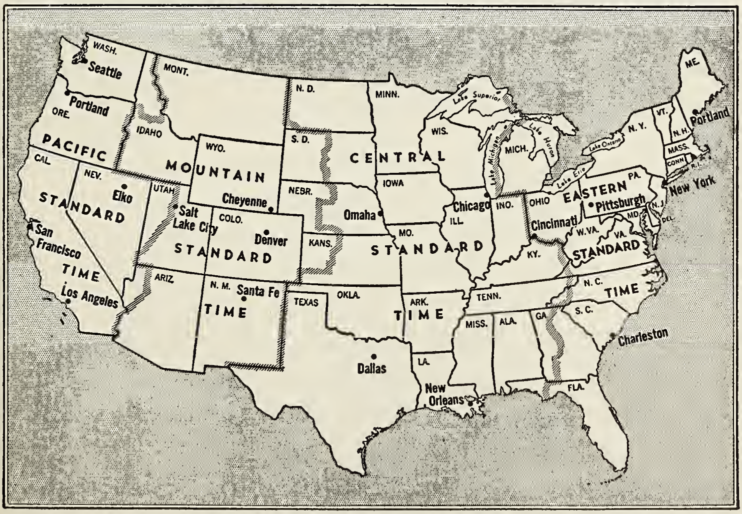



FIG. 3–21. This map shows the time belts of the United States. The boundary lines between adjacent time belts change from time to time.

If you look at the map, Figure 3–21, you will see that the time belts do not coincide closely with their governing meridians. Each town or city decides which time belt it will adopt. At one time, for example, Cleveland used Central Time. But trade relations with the cities in the Eastern Standard Time Belt made it more convenient for persons living in Cleveland to use Eastern Standard Time. In a telephone call to Buffalo, or to Pittsburgh, there is less likely to be confusion if Cleveland has the same time as these cities.

**97. Where does the day begin?** Since one must keep setting his watch back as he travels westward, or setting it ahead if he travels eastward, it is interesting to inquire what happens if he travels entirely around the world. Evidently he gains a day when he travels in one direction, and he loses a day when he travels in the other direction. Where does his day really begin? If it started at Fifth Avenue, New York, it would be most confusing to find Sunday, April 1, on the east side of the avenue, and Monday, April 2, on the west side of the avenue. In order to make the line which marks the beginning of the day pass through water areas throughout almost its entire length, the 180th meridian was chosen.

The International Date Line, at which the day begins, does not follow the 180th meridian all the way, but it bends or shifts to the east or to the west to avoid land areas. [See Fig. 3–22.] If one starts at the International Date Line and travels westward, setting his watch back one hour for every 15° he travels, he will have set his watch back 24 hours by the time he has encircled the globe. *He will have lost one whole day.* In order to make his calendar correct, *he must drop one whole day when he crosses the International Date Line from east to west.* For example, a person crossing this line may go to bed on a Wednesday night, August 3, and find the next morning a placard on his ship announcing that it is Friday, August 5. In that week the traveler had only six days.

If one is traveling eastward across the Date Line, he might go to bed on Wednesday night, August 3, and find the an-

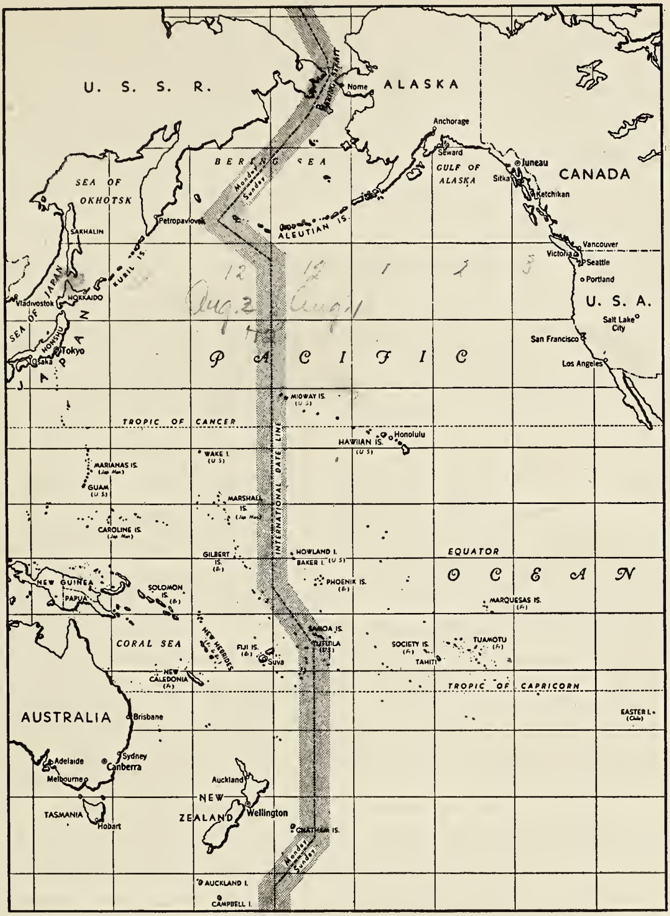



FIG. 3–22. The International Date Line, at which the day begins and ends.

nouncement the next morning that it is again Wednesday, August 3. Thus the traveler *gains* a day. He has a week of eight days, two Wednesdays in the same week. Jules Verne, the French author, used this fact to make a dramatic conclusion for his book *Around the World in Eighty Days.*

**98. Why do we have daylight-saving time?** During the summer months the sun rises early and sets late. Some cities decide each year to set the clocks ahead one hour in the latter

part of April, and then set them back again the last of September, or in early October. Business activities begin and end at the same hour as before, but there is at the end of each day one hour more of daylight for use in gardening, motoring, tennis, golfing, or some other form of recreation. The same reasoning led Congress to adopt war time for the nation beginning in February, 1942.

Of course it is possible to get up one hour earlier without the necessity for changing the clocks at all, but few persons *will* do it. Persons living in the country get up with the sun and utilize all the daylight hours. For that reason, daylight-saving time, which forces them to get up still earlier in order to get milk, fruit, or vegetables to market one hour earlier than usual, is not very popular with farmers. It is not very popular, either, with the mothers of children who try to put them to bed by the clock when the sun is still very high and the streets are noisy from other children still at play.

**99. How did we get our calendar?** When Julius Caesar came into power, the first century before Christ, the calendar was in hopeless confusion. With the advice of the astronomer, Sosigenes (sŏ·sĭj′ĭ·nēz) Julius Caesar established the Julian calendar. Before he changed the calendar, the year began in March, and *Quintilis* was the fifth month. Julius Caesar decided to have the year begin in January, and then changed the name *Quintilis* to *July*, in honor of his name — *Julius Caesar.* Prior to that time, the calendar had been based upon lunar time, or upon the moon. He changed it to make the solar year 365¼ days. Every fourth year became a leap year with 366 days.

Later, when Augustus Caesar came into power, he felt he must be honored, too. Just as Julius changed the name of the month *Quintilis* to *July*, so Augustus Caesar changed the name of the month *Sextilis* to *August*, in honor of himself. To make August as long as July, he filched a day from February.

The Julian calendar then remained almost unchanged until it was revised in the sixteenth century by Pope Gregory. The

time required for the earth to revolve around the sun is not exactly 365¼ days, but it is 365 days, 5 hours, 48 minutes, and 46 seconds. It lacks about 11¼ minutes of being a quarter of a day, which make a difference of 45 minutes every four years, or each leap year. When the Julian calendar added a leap year every fourth year, it was in error about 45 minutes, or in total error about 3 full days in every 400 years.

By the year 1582, the long Julian year had made the vernal equinox fall on March 11 instead of March 21, as it should. Therefore, to correct the error, Pope Gregory ordered that 10 days be dropped from the Julian calendar. For that reason, the day following October 4, 1582, became October 15, 1582.

In order to prevent future errors, Pope Gregory also decreed that henceforth only those "century years" which are divisible by 400 without a remainder shall be leap years. The year 1600 was a leap year, but the years 1700, 1800, and 1900 were not leap years. They are divisible without a remainder by the number 4, but they are not divisible by 400. The old Julian calendar is still used in some places instead of the Gregorian, or new style, calendar. The old-style calendar is now 13 days behind our calendar. Prior to the World War of 1914–1918, the old-style calendar was used throughout Russia.

*100. **Do you like the proposed new calendar?** At different times new calendars have been proposed. A simple new calendar suggests that there be thirteen months of twenty-eight days each, with the first day of each month a Sunday. Then all Sundays would fall on the first, eighth, fifteenth, and twenty-second day of each of the thirteen months. Mondays would always fall on the second, ninth, sixteenth, and twenty-third days of every month. That plan would make it easy to remember the day of the month from the day of the week.

The new month, which would be called *Sol,* would fall between June and July. Thirteen months of 28 days each would give a year of 364 days. The extra day, not included in the thirteen months, would be called "Year day." It would be a

general holiday which would fall between Saturday, December 28, and Sunday, January 1.

When a leap year comes, an extra day would be added between Saturday, June 28, and Sunday, Sol 1. All national and state holidays would fall on the nearest Monday to allow more time for week-end recreation. Such a calendar has considerable merit. Some persons have objected to being forced to pay rent thirteen times each year, but if they received a monthly pay check thirteen times instead of the present twelve, they might become reconciled. Whether the new calendar will ever be adopted is a question that we cannot answer at the present time.

## QUESTIONS

1. How many motions has the earth? What are they?
2. What are the causes for the change of seasons?
3. What causes day and night? Why are the days long in summer and the nights short?
4. Since we are nearer the sun in January than we are in July, why is it warmer in the northern hemisphere in July than it is in January?
5. In what direction is Iceland from the North Pole?
6. There is a straight boundary line between Alaska and Canada. In what direction do you think it runs? Check your opinion from a map.
7. How many seasons would we have if the earth's axis were not inclined 66½° to the plane of the earth's orbit? Explain.
8. What is the meaning of the term *vernal equinox*?
9. Look up the meaning of the word *solstice*. Explain what is meant by the *winter solstice*.
10. Look up the meaning of the word *tropic*. What happens when the sun's direct rays get as far north as the Tropic of Cancer?
11. Explain why the sun's rays illuminate a little more than half the earth's surface at one time.
12. Why is it impossible to see the new moon?

13. Why do we not have an eclipse of the sun every new moon?

14. Why do we not have an eclipse of the moon at every full moon?

15. Mention as many ways as you can in which tides are useful.

16. Why do degrees of longitude vary so much when measured in miles?

17. Consider any place on the equator. Which is farther from it, a village 4 degrees north of it, or a village 4 degrees west of it? Explain.

18. Where do you find the longest degrees of latitude? Explain.

19. How many hours difference in time will there be between a place which is 45° east longitude and one that is 60° west longitude?

20. How do you think an explorer can tell when he reaches the North Pole?

21. Before a vessel leaves port, its chronometer, which is a very accurate clock, is set to read the same time as Greenwich, England. It is not changed, but it keeps Greenwich time throughout the voyage. Two days later, the ship's officer finds that the chronometer shows 3 P.M. when it is noon where the vessel is at that time. What is the ship's longitude?

22. Do the points of the crescent moon ever point toward the sun? Explain.

23. At what hour of the day do you cast your shortest shadow? On what day of the year?

24. A man places a plank on the ground and adjusts it so that it is level and lies in a north-and-south line. Then he hinges to the south end of the plank a straight-edged stick. He then raises the other end of the stick until a line continued along the stick and on upward would point to the North Star. He then uses a protractor to measure the value of the angle at the hinged end. Does that angle have any relation to his latitude? If so, what?

25. What superstitions concerning the moon are still held by some persons?

26. Explain how it is possible for an afternoon paper, which goes to press at 2 P.M. in Chicago, to contain news of a tennis match that is played in Switzerland at 3 P.M. of the same day.

27. Why are eclipses of the moon of so much longer duration than eclipses of the sun?

28. Sometimes, in historical references, one sees the date marked with the letters O. S. (old style). What does it signify?

29. An aviator flying around the earth at the Arctic Circle, which is about 10,000 miles long, might average 200 miles per hour. If he crosses the International Date Line every 50 hours, could he possibly have ten days in a week? Would it be possible for him to have a four-day week?

30. A man was puzzled when he read from a timetable that the train on which he was riding would arrive in Salt Lake City at 2:00 P.M. and leave at 1:15 P.M. How would you explain his perplexity? In what direction was he traveling?

31. The time tables of Continental Europe mark the time for a train leaving at 4 P.M. as 16 o'clock. The 8:00 P.M. train is marked 20:00 o'clock. Can you see any advantage in the plan of marking hours successively from one to 24, instead of using two sets of figures from one to 12?

32. A Rose Bowl game starts at 2:00 P.M. If you live in Denver, at what time will you turn on your radio? When will you tune in, if you live in Chicago? In Atlanta, Georgia? In New Orleans? In St. Louis? In Seattle? In Boston? In Portland, Oregon?

## *Some things for you to do*

1. Find out why some persons in Europe observe Christmas Day on about the seventh of January, 13 days later than our Christmas.

2. An aviator has an airplane which will make 400 miles per hour. Calculate to see whether it is possible for him to fly around the world fast enough at the Arctic Circle so that every day will be Sunday for him.

3. Make a diagram to show the phases of the moon.

4. Find out what the harvest moon is.

# *The World's Food Supply Comes from Green Plants*

What color appears in nature more than any other? In some places which are free from clouds, the blue in the sky or the blue-green of the ocean might give the answer; but the world over, the predominating color of land areas except in deserts and in polar regions, now as in the past, is green. This color is due to green plants.

The green stuff in the plants which determines their color is chlorophyll. Without this almost magical substance, the world as we know it would not have been possible. All living things require food; and green plants are the source of the world's food. It is true that man prepares food for the market and for human consumption; it is true also that man eats animal food. Yet, though many animals eat other animals, the green plant is the fundamental food supply; it is the food of many of the animals which themselves serve as food for still other animals.

Great strides have been made in science, especially during the last twenty-five years. Some foods have been made in laboratories, from chemicals. But even if more and more food can be prepared by chemists, it is unlikely that the green plant will ever be displaced from its unique role of food-maker for the world.

The green plant is as truly alive as its relative, the animal. Just as animals are fitted by structure for their mode of life, so plants are adapted for carrying on their life function. In this unit we shall first consider the parts and activities of a typical plant, then in the second chapter take up the story of food-making.

## *Think about these!*

1. Can you name a plant that has no leaves?
2. Can you name a plant that bears flowers and a plant that never bears flowers?
3. Why are root hairs so important to the life of a plant?
4. Do you know how to tell the age of a tree by examining rings in the sawed-off trunk, and the age of a twig by looking at the markings on the bark?

## *Words for this chapter*

**Petri** (pā′trē) **dish.** A shallow glass dish with a cover.

**Lenticels** (lĕn′tĭ·sĕlz). The openings found in the outer bark of most plants.

**Plastid.** One of the tiny, rounded grains found in certain plant cells and containing the chlorophyll.

**Staminate** (stăm′ĭ·nāt). An imperfect flower, possessing stamens but no pistil.

**Pistillate** (pĭs′tĭ·lāt). An imperfect flower, possessing a pistil but no stamens.

CHAPTER 4 UNIT 2

# What Is a Green Plant?

**101. Are green plants important?** The dog chases a cat over the lawn and on through the garden. Both animals have little concern for the green grass and the vegetables over which they are running. As a matter of fact, such animals have not the mental capacity to understand the importance of plants. Many human beings, whose mental capacities are vastly superior to those of lower animals, hardly ever give a thought to the significance of grass and other green plants. [See Fig. 4–1.]

Yet green plants, either directly or indirectly, have made civilization possible. The story of this basic importance of green plants to the food supply of the world is a magic tale, full of surprises and baffling questions. To understand it, we shall have to look at a living plant, examine its structures, and find out what activities or functions are carried on inside the seemingly almost lifeless organism.

**102. What are the parts of a living plant?** Nearly everyone knows that such a plant as the burdock or chickweed, or a bush like privet or forsythia, or a tree such as a maple or a pine all have parts in common.

FIG. 4–1. Green plants have significance for this scientist. His work is to preserve plants by developing insecticides. In this laboratory he is studying the effects of certain chemicals. The light approximates sunlight, in order to produce conditions like those in nature. (*Courtesy du Pont Co.*)

Underneath the ground all these plants, and indeed most other plants, have roots. Above the ground there is one stem, or, in many cases, there are several stems. From these stems grow branches which bear leaves and at certain times of the year, flowers, fruits and seeds.

This is the general pattern of plant life, yet there are a great many exceptions. Hundreds and even thousands of kinds of plants, such as bacteria and algae, exist without any roots at all. Many of these forms and countless more, such as duckweed and dandelion, have no stems or very short stems. Plants such as mold and cacti have no true leaves. Ferns and mosses never produce flowers. Flowerless plants such as these two, and thousands of other species, never bear fruits and seeds.

**103. What are the important parts of roots?** Some of the simplest roots to examine are those of the carrot or parsnip. From the sides of the carrot or parsnip project a few tiny roots. A skin covers the outside of the root. By cutting

across the root, one can see two portions. The thick, inner core is called the *central cylinder*. Between that and the outer skin is a softer region called the *cortex*. The cortex and the outer skin, taken together, correspond to the outer structure, or bark, of stems. [See Fig. 4–2.]

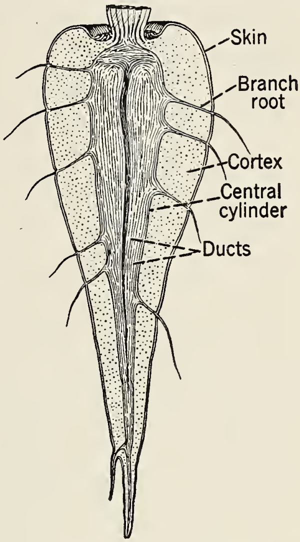



FIG. 4–2. A parsnip root cut lengthwise will reveal the typical structure of fleshy roots. The outside layer is a fairly thin skin. Beneath this is a layer of thin-walled cells called the cortex. The skin and the cortex, taken together, correspond to the bark of the stem. There is a middle and denser core called the central cylinder. In this are the ducts through which soil water ascends to the stem.

This parsnip or carrot is a thickened, fleshy sort of root in which there is a good deal of stored food. Most roots are not so thickened. Pull up a clump of grass and wash off the dirt. You will be surprised to find so many hundreds of tiny, hairlike roots. The roots of a tree such as an apple tree or a maple have an outer bark which covers a hard woody core. Almost all the smaller roots have tiny hairlike growths on them called *root hairs*. These wither or collapse immediately when exposed to the air. Therefore many persons do not know what root hairs are.

**104. What are root hairs?** The best of all ways to learn is to use our own senses. To such knowledge one may add what one learns from others. We can easily study root hairs for ourselves by setting up a simple experiment. Cut circles

from dark green or dark blue blotting paper to fit the bottom part of a *Petri dish.* Thoroughly wet this paper and scatter on it some radish or corn seeds which have been soaking in water for several hours. Replace the cover and keep in a warm (not hot) place. In a few days the seeds will sprout. On all sides of the root or rootlets, a white furry growth will appear. This consists of hundreds of root hairs. If we use a hand lens or the low power of a microscope, we can see individual hairs.

**105. Of what value are root hairs to a plant?** Plants, like animals, must have water. Animals have various means of getting water into their bodies. Larger animals drink water; smaller ones may absorb it through their outer covering. Many animals live in water, either fresh or salt. A plant, obviously, has no mouth and no means of drinking water. A small amount of moisture may be absorbed by the stems and leaves. Most of the water, however, that enters a plant comes in through the root hairs. Perhaps you are thinking of tiny openings in these hairlike structures. If so, you are wrong. If there were openings in the root hairs, not only would no water enter; the protoplasm of the root hairs would ooze out and be lost.

Recall your study of last year. The absorption of digested foods through the intestinal wall into the blood, the entrance of oxygen into the blood in the air sacs of the lungs, and the escape of carbon dioxide from the blood into the air sacs, were all examples of a process called *osmosis.* Several experiments were performed showing how certain substances pass through membranes.

Water enters the plant through the root hairs by the same process of osmosis. Let us consider a single root hair and see how this is possible. Inside the root hair is a rather dense liquid – *cell sap.* In the ground, outside the root hair, is water. Separating the cell sap and the water is the membrane of the root hair. There is much less water inside the cell sap than there is outside. Hence the water in the ground tends to

diffuse through the membrane of the root hair into the inside of the root hair. More and more water comes in until the contents are very watery. This root hair is separated from the next cell inside the root by one or two membranes. The cell sap in the cell next to the root hair has less water than the watery contents of the root hair. So the law of osmosis again applies, and some of the water diffuses through the cell membranes and walls into the next cell. This is repeated from cell to cell until the water reaches the outside of the central cylinder seen clearly in a fleshy root like the parsnip, or the woody core of a root like the maple tree.

**106. How is water carried up through the root?** In the outside parts of the central cylinder or the woody region of a root are long cells which are like tubes. They are fitted end to end, though the ends are separated from each other by a thin cell wall and membrane. These tubes are called *ducts,* from the Latin word *ducere* meaning *to carry* or *lead.* The walls of many of these ducts are strengthened by spiral bands or ridges. Again by osmosis, the water passes from one long duct to another one above it. [See Fig. 4–3.]

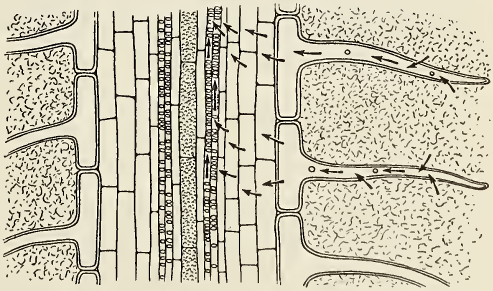


FIG. 4–3. By osmosis, soil water penetrates the thin-walled root hairs. Then it passes on into the next cells. Finally it reaches the tubular ducts, through which it rises into the stem.

**107. How can we experiment to show where liquids ascend in a root?** It is a very simple matter to see where the ducts are in a root such as a carrot or a parsnip. Take two or three of these roots and cut off about one inch from the lower end of each. Then stand the roots in a jar of water to which red ink poncean 3R, or green S. F. has been added. Let the

roots stand for several days. Then, with a knife, cut off several cross sections until a definite ring of red is shown. Can you tell whether this stained portion is in the cortex or the central cylinder? Take another root and cut it lengthwise through the middle. An examination of one of these halves ought to help you to answer the previous question. Can you explain why only certain portions of the root are colored red? [see Fig. 4–4.]

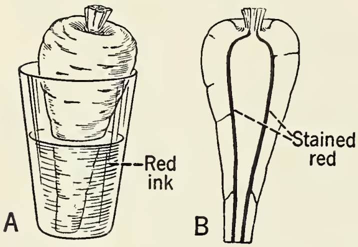



FIG. 4–4. A. A parsnip root from which the end has been cut off, has been standing in red ink for several days. B. This root, sectioned, shows where the ducts are.

**108. How do we know that roots are storehouses for food?** Everyone knows that roots such as beets, sweet potatoes, carrots, and parsnips are used as food by human beings. This proves that such roots do store food. By simple tests, scientists have found that almost all roots, at least those that are thickened, store up food.

Is this food of use to the plant in the cases where man does not use it himself? The leaves and frequently the stems of many plants die before winter comes. Such plants would have little food with which to start the new growth of buds and shoots in the next spring unless the roots had stored up food for just such an emergency. Trees, shrubs, and smaller plants that live through the winter, draw upon their supply of stored food when growth starts in the spring.

**109. Of what value are roots to plants other than for absorbing water and storing food?** Try to pull a dandelion plant up from the ground. It does not come up easily. Try next a plant with a longer stem, such as a burdock or a pigweed. You will find this, too, is rather difficult to pull up.

Even a clump of grass is loosened from the ground only with difficulty.

Of what particular advantage to the plant, then, is the root system, in addition to absorbing matter and storing food? The support given to the plant by the roots is exceedingly important in huge trees. The branches, twigs, and leaves of a tall or spreading tree must withstand the pressure of the wind in a storm. However, unless the wind reaches hurricane force, most trees are so securely rooted that in their prime they can successfully resist average storms. Roots of trees have been known to extend more than one hundred feet away from the main trunk. [See Fig. 4–5.]

FIG. 4–5. The root systems of some plants and trees are often amazingly long and complicated.

**110. How do stems vary in shape?** Most stems are fairly straight. Some stems, however, have the climbing habit. Some vines like the grape, morning glory, and wild cucumber develop *tendrils*, curious spiral structures which clasp objects and hold the vine in place. Others, like poison ivy, develop little air roots which hold the plant securely. Some plants like the climbing bean, hops, and morning glory, twine around the support. Some of our wild vines may be hundreds of feet long. Vines which are a fifth of a mile long have been reported from the tropics. [See Fig. 4–6.]

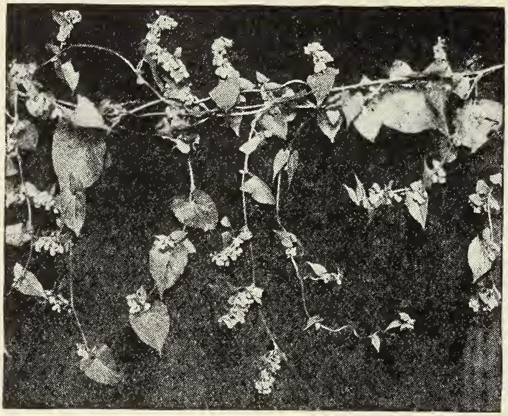


Fig. 4–6. Climbing false buckwheat is a common vine in woods, thickets, and fields. It ranges from Canada south to Florida and west to Nebraska. (*Courtesy Brooklyn Botanic Garden*)

*111. What are some different kinds of stems? From your past experience you know that most plants have one or more stems, or, as they are called in trees, trunks. The stem and its branches constitute a large part of most plants. Sometimes, as in the palm, corn, and young asparagus, the stem is unbranched. Usually, as in the willow and the honeysuckle, it has many branches. The stem is important because it bears the leaves, also the flowers and fruits when they are in season. Usually the stem of a plant is erect and tall, thus bringing the rest of the plant, except the roots, up into the air and the light.

In certain plants like the dandelion, the stem is short and flat. In many other plants it extends horizontally under the ground. The common potato is a type of underground stem, called the *tuber.* The little buds scattered over it prove that it is really a stem. Quack grass has another type of underground stem called a *rootstock.* The rootstock of quack grass seems to be jointed. From each of these joints, buds may arise and develop into upright stems. Bermuda grass, Solomon's seal, and the yellow water lily, together with many other plants, also have such underground stems. [See Fig. 4–7.] The stems of trees and the stems of most shrubs are rather hard, because they have so much wood in their struc-

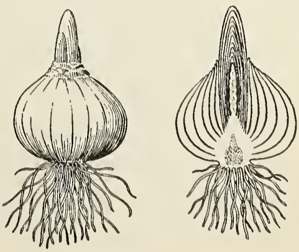

FIG. 4–7. Certain plants, of which quack grass and Solomon's seal are examples, develop underground stems.

ture. They are called *woody stems* in contrast to the softer stems of such plants as garden vegetables, grass, and most small plants.

A *bulb,* still another kind of underground stem, is a fleshy, rounded object made up of many layers. An onion, which you can buy in the grocery store, is a bulb. The hyacinth, tulip, amaryllis, and many other flowering plants also reproduce by bulbs. [See Fig. 4–8.]

**112. What is the largest stem in the world?** There are many huge trees in the world, but none so tall as the Sequoia

FIG. 4–8. A bulb, such as an onion or a hyacinth, is really an underground stem. It is a rounded, compact mass of many layers, usually containing a cluster of flower buds.



and redwoods of California. Some of these trees' stems, or trunks, extend over 300 feet (the tallest is 340 feet high) above the ground. Such a tree may be from 25 to 35 feet in thickness at the base. [See Fig. 4–9.]

FIG. 4–9. The redwoods of California are the most magnificent trees in the world. They tower to a height of over 300 feet, and are so huge that a driveway large enough for an automobile has been built through the base of one of them. The wood of these trees is useful for a variety of purposes. (*U. S. Forest Service Photo*)

In one place a roadway has been cut through the trunk of the tree large enough so that an automobile can be driven through it. In fact, the Sequoia is not only the largest living organism, but it is also the oldest. The "General Sherman," a giant Sequoia, is considered to be nearly 4000 years old.

**113. What parts of a woody stem can be observed on the outside?** The stems of many common plants are green and fairly soft. The stems of shrubs are usually more or less brown and have a bark on the outside. This bark can be studied better in the stem of a tree, such as the horse chestnut which has large buds and clear markings. Let us examine a twig of horse chestnut and note all the parts. [See Fig. 4–10.]

If the twig was cut in the fall or winter, leaf buds and perhaps a flower bud, for the next season's growth, will be seen. If the twig was cut in the spring, it will bear expanded leaves,

FIG. 4–10. The young, tender leaves and flowers of the horse chestnut expand in the spring. (*U. S. Forest Service Photo*)

and possibly a flower cluster. Scattered over the surface there will be many little spots. Such spots are really openings in the bark. These openings, called *lenticels*, are much larger in the bark of the cherry and the birch. Through them, a certain amount of water and maybe some of the waste gas, carbon dioxide, escape into the atmosphere. Also, some air, containing oxygen, can enter the plant through the lenticels. It must be evident that the bark, like our skin, protects the parts underneath. In old trees the outer bark tends to split and crack into ridges, furrows, or scales. These markings are so characteristic that one can learn to recognize different trees by their external appearance.

There are other markings on this horse-chestnut stem. Note the triangular scars, each with several dots. These markings were left when a leaf dropped off in the autumn. Each of the dots or raised spots marks one of the veins of that leaf. Look

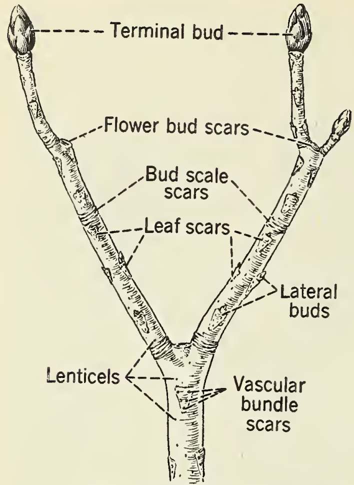



FIG. 4–11. The twig of the horse chestnut has all the typical stem markings. In the winter one can see the big, sticky leaf buds at the ends. If there is a flower bud, it will be found in a crotch. Triangular leaf scars and the scars of last year's buds are evident. The small holes are lenticels.

at the position of these leaf scars on the stem and tell whether they occur singly or in pairs. What relationship can you see as to the position on the stem of two adjacent pairs?

If the stem bore a flower cluster last year, there will be a flower scar, which you can usually find at the fork of two twigs. [See Fig. 4–11.]

Examine the stem further, and you will find still other markings. These are made up of tiny lines or scars, encircling the stem at various points. They are bud-scale scars. When the bud at the end of the twig opens in the spring and the contents expand into a leaf, the scales which covered the bud during the winter drop off. Each bud then leaves scars of its scales. Since this occurs only once a year, in the spring, we can easily calculate the age of the stem by counting back from the growing extremity to successive bud-scale scars. If the amount of stem produced in a certain year was less than the average or much more than the average, this should be a clue to the kind of weather, good or bad, for growing during those particular seasons. It is an interesting project thus to calculate the ages of stems and twigs. It is not possible, however, to calculate the age of older stems by this method because the cracks in

the bark destroy the older, bud-scale scars. Certain trees do not have distinct bud-scale scars.

114. **Is there more than one bark?** We are now ready to examine the bark more closely. By using a knife, you can very quickly peel off or scrape away the outermost layer of bark. You should stop as soon as you see anything green underneath. Examine this outer bark and the green bark to see whether or not the lenticels of the outer bark extend into the green bark. Feel this green layer, and then cut it. Compare the outer and the green barks as to texture and other characteristics. This green bark is valuable because it manufactures some food for the plant. Scrape away this green bark and you will find a whitish inner bark underneath. Cut a little of this bark away and pull it to pieces; then tell whether its parts, or fibers, extend longitudinally (parallel with the stem), or whether they extend around the stem. This inner layer is perhaps the most important of these three barks, because foods, manufactured in the upper part of the plant, are sent down through it into the roots or the stem. [See Fig. 4–12.] It is *bast*, of which you have read earlier in your study of science.

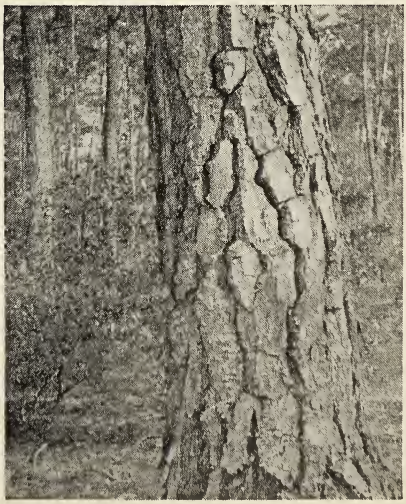


Fig. 4–12. As the pine tree gets older, new layers of wood are formed. Young bark can stretch. Old, brown bark is dry and brittle. As more and more growth of wood within pushes against the outer bark, it begins to split and crack. The trunk of a growing tree thus gets larger, but a given spot does not get farther from the ground. It does not grow upward.

**115. What are the parts of a woody stem underneath the bark?** As you strip off the inner bark from a section of a horse chestnut, or some other kind of stem, you will notice how smooth and moist is the wood that is found directly underneath. This wood will be particularly smooth and moist if the specimen is a fresh branch cut in the spring. This outer part of the wood is the part of the stem where growth takes place. It is called the *cambium*. There is considerable liquid food here for the growing cells. This makes the wood moist.

Let us cut the stem across and look at one of the cut ends. There are several rings. Inside the inner ring, there appears to be a substance somewhat softer than the surrounding wood. This is called *pith*. Some stems have much more pith than others. Whether pith will or will not be found in a branch of a tree is usually determined by the age of the branch. Pith is usually present in young stems, but in older stems it changes to wood cells, making a dark region there known as heartwood. The heartwood of a tree is usually dead.

**116. What are annual rings?** Let us say that from the bud-scale markings we had previously determined that this particular horse-chestnut stem was three years old. In places having a winter, the growth of shrubs and trees gradually slows down as the temperature drops in the fall. The wood cells formed at this time are very small. Finally, during the winter, no new cells are formed. Then, in the spring, there is great activity in plants. Sap comes up from the roots, buds swell and open into leaves and flowers, and a layer of new wood cells, very much larger than the small cells of late summer and autumn, grows in the cambium region over the last cells of the preceding year. The difference in size between the small autumn cells and the large spring cells shows as a band. Because this ring of cells is formed once a year in the spring, such a ring is called an *annual ring*. Now it should be clear that a tree is as old in years as the number of its annual rings. The stem we examined externally should reveal three annual rings. [See Fig. 4–13.]

FIG. 4–13. The difference in size between the small autumn cells and the large spring cells makes a band in the wood of a tree. One band is formed each year. These annual rings show how old the tree is. (*U. S. Forest Service Photo*)

Earlier in this chapter, reference was made to the Sequoia trees of California. Now you can see why men are scientifically certain that most of these trees are much older than the Christian era, even several thousands of years.

Another thing can be learned from examining the annual rings in a tree. Scientists can give a good estimate of the amount of growth during any one year. If the season – say fifteen years ago, or fifteen hundred years ago – was very dry and cold, fewer wood cells would have been produced. On the contrary, a warm, moist season might have brought about the production of two or three times as many cells. This would be revealed in the reduced size of the band of cells produced in a particularly dry, cold year, even hundreds of years ago, also in the wider band during another year adapted for good growth. By such means, certain scientists have been able to estimate the general dates when prehistoric Indian cliff dwellings originated. These scientists have counted the annual rings in the wood used in old wooden structures found in the Southwest, and have estimated the amount of growth in the different bands. Then they have compared the widths of the annual rings in this wood with the widths of annual rings on trees where dates were well known and so have arrived at their conclusions. [See Fig. 4–14.]

FIG. 4–14. This is a section of a log of western yellow pine, 670 years old. The ring to which the man's forefinger points was formed the year St. Augustine was founded — 1565. How do you think this fact was discovered? (*U. S. Forest Service Photo*)

**117. Through what part of a woody stem do liquids rise?** The water taken in by a plant through the roots is destined for the parts aboveground. Evidently the stem is the only means of bringing liquids to the upper parts of the plant. You learned that there were ducts in the root, and you proved their presence by staining them. In similar fashion, let us stand a number of kinds of stems in a jar of water and red ink. This experiment cannot be expected to give conclusive results for several days. If the stems are cut while actively growing and quickly put into water, the results will be apparent much more quickly. If, at the proper time, the stem is split lengthwise, the ascending red ink will have left a telltale mark where the red fluid went up through the ducts of the stem. This region will be found to be just inside the cambium. It is true, then, that liquids in a growing stem are descending in the tubes of the white bark, while close to them other liquids are ascending through the ducts in the outer part of the wood. We do not see any of this activity, nor has any type of X-ray instruments or other apparatus yet been invented that will let us peer through the dark walls of a stem and observe these movements. We shall have to use our imaginative powers to realize

that in an apparently lifeless tree trunk, during every minute of the twenty-four hours of every day of the growing season, this ceaseless movement takes place, in two constant streams, side by side yet moving in opposite directions.

**118. How are liquids carried across a woody stem?** Just as there are streets cutting across the main thoroughfares in a city, with their crosstown trolleys and busses, so in a stem there are transverse, or " crosstown," channels. In the cut-off cross section you will see lines radiating out through the wood. They extend clear to the cambium. Each of these lines is called a *ray*. Through the rays, water and digested food can be carried to different parts of the stem.

**119. What kinds of stems are there other than woody stems?** Many plants like grass, grain, weeds of many kinds, and numerous flowering plants and vegetable plants have little or no wood in their stems. Their stems are not strong enough to support a large plant. There are also stems of plants like corn, bamboo, and others, where there is a sort of woody rind on the outside. The interior of such stems is filled with large, soft, pith cells in which are scattered ducts appearing like threads. Plants like the bamboo may become tall trees.

**120. What is a leaf?** Most plants have many twigs or branches of the main stems, which in the growing season commonly bear leaves and sometimes flowers.

Look at a simple leaf such as a geranium or a maple. You see a leaf stem which botanists call the *petiole* (pĕt′ĭ·ōl). Not all leaves have petioles. There may or may not be little leaf-like parts at the base of the leaf. If they are present, they are called *stipules* (stĭp′ūlz). In the pansy and many other plants they are quite conspicuous. The most important part of the leaf is the *blade*, which is usually broad and thin. The prevailing leaf color (apart from variegated leaves) is green except when leaves are changing color in the fall.

The leaves are perhaps the most conspicuous parts of plants. They are also invaluable for the continued life and growth of

plants. That this is true will be evident after we have considered the structures of leaves and the activities carried on in these structures.

*121. **What kinds of leaves are there?** There are hundreds of kinds of leaves which vary in shape, size, color, texture, and many other characteristics. They are usually classified or grouped in two divisions: *simple* and *compound.* A simple leaf is one that has only one blade. A compound leaf, on the contrary, has several blades supported on one petiole. The leaf of an elm tree, a lily, or a geranium is an example of a simple leaf. The rose, the horse chestnut, and the ash all bear compound leaves. [See Fig. 4–15.]

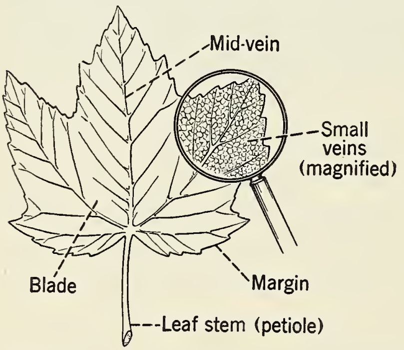



Fig. 4–15. This simple maple leaf reveals all the parts of a typical leaf. The petiole supports the broad, wide blade. Throughout the blade are innumerable veins carrying water to the leaf and taking away manufactured food.

Examine a leaf such as the maple. You will note several ridges or veins extending through the blade from the base out to the edge, or the *margin* of the blade. From each of these veins extend many smaller veins. In fact, a closer observation reveals a network of large and small veins extending throughout the blade. Where the veins of a leaf are very much branched, the leaf is said to be *netted-veined.* There are several kinds of netted-veined leaves. The veins in a maple leaf radiate out somewhat like the fingers in a hand. Such a leaf, therefore, has what is called *palmate-netted veining.* The elm leaf, however, has a simple, heavy midrib, or vein, extending from the base to the extremity of the leaf. From this midrib branch off many other veins. Such a leaf is said to have

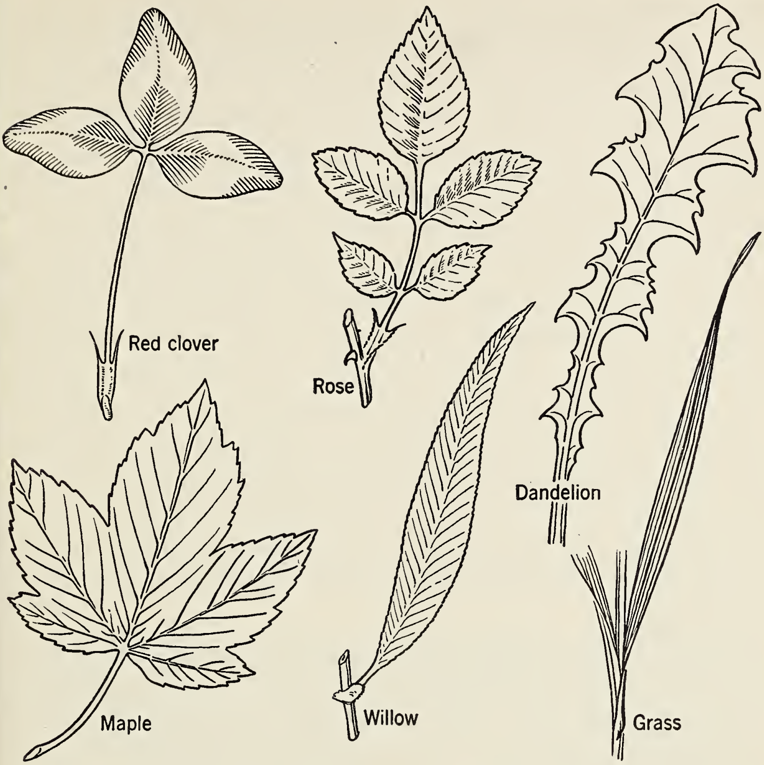



FIG. 4–16. Here are examples of two kinds of compound leaves and four kinds of simple leaves. The grass has parallel veining; all the rest have netted veining.

*pinnate-netted veining* (from *pinna,* the Latin word meaning *feather*). [See Fig. 4–16.]

If now you look at a blade of grass or a lily leaf, you will find veins extending more or less parallel from the base to the extremity of the leaf. These are called *parallel-veined* leaves.

These are examples of the three types of veining found in leaves, but not all leaves are true types.

122. What are the internal parts of a leaf? A leaf blade is so thin and delicate that we shall have to use a magnifying glass and even a microscope to understand the structure of a

leaf. A skin, or *epidermis,* covers both the upper and the lower surfaces. In certain leaves, pieces of this skin can be pulled away from the rest of the leaf, if a slight cut is made first. Take a leaf such as that of the geranium, and gently scrape it with a knife blade. You will find some soft, green stuff on the knife blade. Does it resemble any part of the stem? This green material is called *chlorophyll.*

If you can peel off a tiny bit of the skin on the lower side of a leaf, place it on a microscope slide, add a drop or two of water, and place over it a cover glass. Then look at it with the microscope, using the low power. You should see tiny holes arranged in a sort of pattern. There are little openings, usually on the underside of leaves, leading into the interior of the leaf. Each opening is called a *stoma* (plural, *stomata*). The two cells, one on each side of a stoma, are called *guard cells* because they regulate the size of the openings and thus control or guard the passage of water vapor and gases through the stoma.

If you cut across one of the big veins of a leaf, and look at the cross section with a magnifying glass, you should be able to see tiny openings. The veins resemble several pipes or tubes grown together. Evidently they can carry liquids. What liquid do you know that is carried up through stems? The veins of leaves are really continuations of the ducts of the stem. They are adapted to bring the soil water into the blade of the leaf. They also carry digested food to the tubes in the white bark, by means of which it goes downward in the stem.

If you examine the leaf more carefully, you will find that besides the upper skin, or epidermis, and the lower epidermis in which stomata are found, there are two more layers of cells. These are the *palisade cells* — so called because the cells of this layer stand on edge like a palisade or fence — and the *spongy cells.* Between the spongy cells, are air spaces which provide chambers leading to the stomata.

**123. What does a leaf cell containing chlorophyll look like?** We must again use the microscope for assistance.

Take a simple leaf of a water plant called *Elodea* (ē·lō′dē·ȧ) or *Anacharis* (ȧ·năk′ȧ·rĭs). Mount it in water on a well-warmed microscope slide. You should see many cells, in each of which may be seen numerous rounded particles, each of a bright green color. Such rounded bodies are *plastids.* The soft, green chlorophyll which you previously scraped from the leaf is found in these plastids. There are more plastids in the palisade and spongy cells than elsewhere in common leaves. If the Elodea is sufficiently warmed, it may be possible to observe these plastids moving around the interior of each cell, somewhat like skaters in a rink. It is known that the plastids will move toward the part of a cell where they will get the greatest light. Chlorophyll and light are partners in a strange scientific process. This is a story which will be told in the next chapter.

**124. How do plants reproduce?** One very important function of plants is that of reproduction. This function does

FIG. 4–17. The sunflower is composed of dark flowers in the center, and raylike ones outside. (*Courtesy Ferry-Morse Seed Co.*)

not aid the individual plant to live. But it does keep this kind of plant alive on the earth.

Plants may be broadly divided into two groups: those that bear flowers and those that are flowerless. [See Fig. 4–17.]

There are some plants that are in bloom most of the year. However, most plants bear flowers during a limited period. Flowering plants commonly reproduce by means of seeds, produced after the flowers have come and gone. Many of the flowering plants also reproduce by other means than seeds. Flowerless plants usually reproduce by *spores* but also by several other methods.

**125. What is a flower?** Human beings appreciate flowers for their colors and odors. Bees, butterflies, moths, and hummingbirds are also attracted to flowers by color and odor and also by nectar, a sweet syrup produced by most flowers. Incidentally the story of the honeybee and flowers means a great deal to man, for this relationship provides not only honey, but also fruits and seeds which otherwise might not be produced.

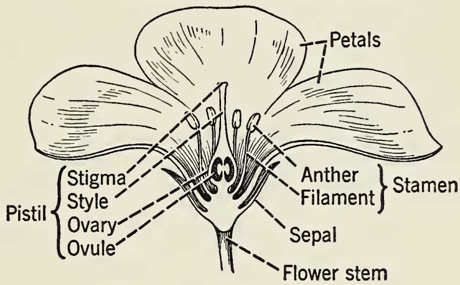
The flower seems to be an attractive advertisement to get bees and other insect visitors to come to the flowers. How this aids the plants will soon be discussed.

**126. What are the parts of the flower?** If you are provided with a flower such as an apple blossom, a buttercup, a single rose, or other flower that has all the floral parts, it is a very simple matter to find and name them. The colored, showy part of the flower is called the *corolla* and each separate division is called a *petal.* Outside and underneath the corolla is the *calyx,* usually green and divided into little leaflike parts, each called a *sepal* (sē′păl). By examining a bud of the flower you are observing, you will see how valuable the calyx is to the flower before it opens. Remember that there are many kinds of insects, especially ants and beetles, that would like nothing better to eat than the tender petals of a young flower.

Inside the corolla there are usually several slender parts surrounding a central rod. Each of these slender parts is a

*stamen,* of which the stem is the *filament,* and the top — usually brown or yellow — is the *anther.* Shake one of these stamens over your hand or over dark paper. The dust which falls is called *pollen.* [See Fig. 4–18.]

FIG. 4–18. A complete flower is one which has the four floral parts. The essential organs are the stamens and the pistil. A flower lacking either pistil or stamens is not only incomplete, but it is imperfect.




The central rod is called the *pistil.* It consists of three parts. The top, on which you may find some tiny hairs, is the *stigma.* The long stem is the *style.* The green, rounded base of the pistil is the *ovary.* Cut open the ovary and you will find one or more little green, unripe objects that look like little seeds. However, they are not yet seeds and for the present we must call them *ovules.*

A flower having calyx, corolla, stamens, and pistil is said to be *complete.* Many flowers are *incomplete* because they lack one or more of these parts.

Some plants produce two kinds of flowers. The corn is an example. The tassels at the very top of the cornstalk are *staminate* flowers, imperfect because they lack pistils. The stamens of these tassels produce the corn pollen. The other flowers are *pistillate* and also imperfect because they lack stamens. These pistils are the " silk " which protrudes from the end of the ear of corn. Each green strand of " silk " is a single pistil ending in a stigma and leading down, or in, to an individual corn kernel, which is really an ovule.

**127. How does the bee help in the making of seeds?** Like children, honeybees are fond of sweet liquids. They sense that there is nectar in flowers and that is the reason you

see these insects continually buzzing around flowers. The body of the bee is hairy. As she crawls down into the lower part of a flower where there are usually several drops of the nectar, she generally brushes some of the anthers of the stamens. Whenever her body touches this dusty part of a stamen, some pollen is caught on her hairy body. She may even be gathering pollen for food in the hive. Bees go from flower to flower seeking nectar or pollen. As the bee enters each new flower, it is more than likely that some pollen will be brushed off from her body upon the top of the pistil. On the stigma there is a sweet, sticky substance that holds this pollen securely, once it lodges there. Sometimes the wind, or, in some water plants, the water current, instead of the bee, carries pollen from the stamens to the pistil. In some plants the flower is so constructed that the pollen falls or is thrown on the stigma from the stamens of the same flower.

This carrying of pollen from the stamen to the stigma is called *pollination.* If it takes place in one flower, it is called *self-pollination.* If the pollen is taken from the stamens of one flower to the stigma of another flower of the same kind, it is called *cross-pollination.*

128. How may the wind help in pollination? In many plants such as grasses, corn, rye, birches, pine, elm, and oaks, the pollen is light and is carried from one plant to another by the wind. The stigma of the pistil of the flowers of such plants has tiny hairs on it which serve to catch and hold the pollen. Look at the end of one of the strands of " silk " of an ear of corn to see the hairs on it. Toward the end of May in northern states, pollen from pine trees may drop like clouds of sulfur.

129. What happens to the pollen that lodges on the stigma? The sweet liquid on the top of the stigma seems to nourish the pollen grains that lodge there. Soon they begin to sprout, and from each grain, if conditions are right, there will grow out a slender tube so small that it cannot be seen without a microscope. Inside this tube is fluid protoplasm, and also some important nuclei.

Pollen tubes can be sprouted in the school laboratory. Put several drops of a weak solution of sugar and water on a microscope slide. Then drop on it some pollen from rather old sweet pea flowers. [See Fig. 4–19.] Other pollen may also

FIG. 4–19. This photomicrograph shows a portion of the stigma of a lily flower, enlarged enough to show the cells of the pistil and four pollen grains which have lodged there. Each pollen grain has started to form a pollen tube. In this tube are several important nuclei, one of which is the sperm nucleus. Do you know what will happen when the first pollen tube reaches one of the ovules in the ovary?

be tried. Put a cover glass over the pollen and keep in a moist place such as a covered Petri dish. Put this in a warm room, and in a few hours some of the pollen grains should have sprouted. Observe them under the microscope.

The pollen tubes sprouting on the stigma start to grow downward inside the style. Down they go in a veritable race. Soon some of the pollen tubes penetrate the ovary. Then the foremost pollen tube turns aside and enters one of the little ovules. When it gets inside the ovule, its most important nucleus joins the nucleus of the egg cell of the ovule. This process of the fusing of the nucleus of the pollen (the sperm nucleus) and the nucleus of the egg cell, is called *fertilization.* The actual fertilization in animal cells is about the same as this. A sperm, or male nucleus, fuses with the female nucleus of an egg cell.

**130. What follows fertilization?** As soon as the first pollen tube has delivered its nucleus to an egg cell, the rest of the tube withers. If there is only one ovule in the ovary, the other

pollen tubes die. If there are many ovules, the pollen tubes reach them and each of the waiting egg cells normally receives a nucleus.

When fertilization has been completed, several changes occur in the flower. The colored advertisement is no longer displayed; that is, the petals wither and fall. The sepals may also fall, but in many cases they become fleshy and later make up a part of the fruit, as in the case of the apple. The stamens soon wither, as does the upper part of the pistil. But the lower, rounded ovary immediately begins to grow larger. Instead of being obscure and hidden as at first, the ovary soon dominates all the rest of the flower. As it develops, its color usually changes. Instead of being green and hard, it may take on bright colors and become soft. Frequently it develops pleasant flavors and odors. It has now become the fruit. When the fruit is thoroughly ripe, it will be found that its ovules have grown correspondingly and have now become seeds. The fruit, then, might well be called a ripened ovary, together with any other closely connected parts.

**131. What is the difference between a seed and a seedling?** By cutting open a seed such as a soaked pea or bean, you will find a little undeveloped plant, or embryo, all ready for further growth if kept warm and moist. Surrounding the plant is usually a considerable quantity of stored food for the use of the tiny seedling when it first starts to grow in the ground.

By planting various seeds and observing the seedlings that develop, you may learn many interesting facts about methods of breaking through the ground, the formation of roots and stem, and the development of the first leaves. The seeds of trees are usually much slower to germinate and sprout than are the seeds of garden plants.

**132. In what ways other than by seeds do flowering plants reproduce?** It is not an uncommon sight to see little, new growths coming up from one of the roots of a poplar tree at a considerable distance away from the trunk. Similarly

maple, chestnut, and oak sprouts usually come up from the stump of a parent tree after that tree has been cut down. There are many other plants from whose roots one or more new plants will come. If you plant a piece of the root of the rhubarb, horse-radish, dandelion, dahlia, or peony, a new plant will spring up. A sweet potato, carrot, beet or parsnip will also give rise to a new plant.

The rootstock or underground stem of Solomon's seal, quack grass, Bermuda grass, and sweet flag will bear new plants wherever it is budded. Likewise the common white potato is cut into pieces, each containing one or more buds, and is planted instead of seed for a new potato crop. Sugar-cane stems are cut into short lengths, and these are the means of starting new plants for another crop of the sugar cane. [See

Fig. 4–20. Sugar-cane stems are saved to be cut into short lengths and planted in order to produce a new crop of sugar cane. Roots sprout from the sides of the cane, and soon a new plant comes from the ground.

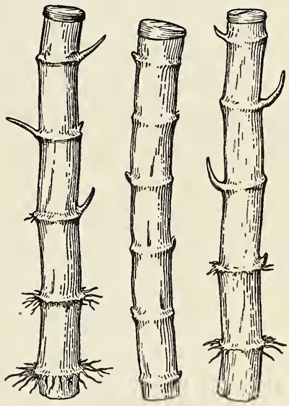


Fig. 4–20.] Bulbs such as hyacinth, narcissus, tulip, onion, and many lilies are examples of many-layered, compact stems which grow into plants. In a few cases such as the begonia and the Bryophyllum (brī′ō·fĭl·ŭm), new plants may arise from a single leaf left on the moist, warm ground. A fresh branch of the willow tree or a broken-off twig of a geranium plant will develop roots if kept in water, and if then planted will easily grow into a full-sized plant of its kind.

## Questions

1. What makes a plant green?
2. What are the main parts of a typical green plant?
3. Of what value is each part to the plant?
4. Can you name several uses to man of each part of typical green plants?
5. How is soil water absorbed by the root hairs and how does this water pass through the cells of the root?
6. How would you experiment to show where liquids ascend in a root? In a stem?
7. How can you tell how old a twig is by the external markings?
8. How do you think buds can remain alive on shrubs and trees through freezing weather in the winter?
9. What barks are there on a typical woody stem?
10. What is the internal structure of a typical woody stem?
11. How can you tell the age of a tree by its internal structure?
12. Can you trace the course of a drop of water from the soil to the cells of a leaf?
13. Since the ducts are not continuous tubes from roots to leaves, can you explain why water pressure does not burst the lower parts of the trunks of Sequoia trees?
14. What is sap?
15. How do stems vary in shape?
16. Can you name several kinds of leaves according to number of blades, veining, and other characteristics?
17. What is the internal structure of a typical leaf?
18. What is a bulb? Give some examples.
19. What is the difference between a rootstock and a true root? Give examples.
20. How can pollen tubes be grown in the school laboratory?
21. Can you name the parts of a complete flower and give the special use of each part?
22. Some strawberries bear stamens but no pistils, others bear pistils but no stamens. From which would you expect to get fruit? Explain.

23. Why is the honeybee of such great importance, other than for the making of honey, to agriculturists and farmers?

24. Can you distinguish between a fruit and a seed? A seed and a spore?

25. How does a seedling differ from a seed?

26. In what ways other than by seeds do flowering plants reproduce?

## *Some things for you to do*

1. Count the stomate openings in a given part of a leaf (previously marked off by India-ink lines); then calculate the probable number in that leaf. By carefully counting the number of leaves on one branch of that tree in full foliage, then counting the number of such branches, a rough estimate can be made as to the probable number of leaves on that tree. Multiply to obtain the possible total number of stomata on the leaves of that tree.

2. Cut some stems of horse chestnut, ash, apple, lilac, forsythia, and other trees or shrubs in the middle of the winter, and place the stems in water, indoors. Note the expanding of the buds as the leaves or flowers contained in the buds start to grow and to develop.

3. Try the experiment of warming an Elodea leaf in water and looking at it with a microscope to see the parade of the plastids.

4. Grow some pollen tubes and make drawings of them as seen under the microscope.

## THINK ABOUT THESE!

1. Do you know why the farmer is so anxious to kill potato bugs on his potato plants although these insects never molest the potato tubers underground?
2. What is meant by saying that coal is bottled sunlight?
3. Can you name ten products other than food obtained from plants?
4. Why do plants require water in order to live?

## WORDS FOR THIS CHAPTER

**Catalyst** (kăt′*ȧ*·lĭst). A chemical substance which acts to change the structure or character of other substances without being changed itself.

**Carbohydrate.** One of several groups of compounds containing carbon, hydrogen, and oxygen, with the hydrogen and oxygen in the same relative amounts as in water. Carbohydrates form one of the major classes of foods for man.

**Photosynthesis.** The process of carbohydrate formation in leaves; uniting carbon dioxide and water by chlorophyll in the presence of light.

*CHAPTER 5* ———————— *UNIT 2*

# *How Do Green Plants Make Food?*

**133. Can starch be produced in leaves?** First of all, we need to know that chemists have experimentally found out that starch consists of the elements carbon, hydrogen, and oxygen. There are present in starch six atoms of carbon for ten atoms of hydrogen, and five atoms of oxygen. The plant takes these elements from the carbon dioxide in the air and from water in the soil.

We are now ready to perform an interesting experiment to see whether we can find out what the relation of chlorophyll is to starchmaking.

Select a vigorous geranium plant. Cut two slices from a large cork, then cut two pieces of black carbon paper the same size as the pieces of cork or slightly larger. Place the two pieces of carbon paper on opposite sides of a healthy leaf, over the same region. Over each paper, place one of the two pieces of cork. Now hold papers and cork securely in place by pressing two pins diagonally through the corks and the leaf, one from each side.

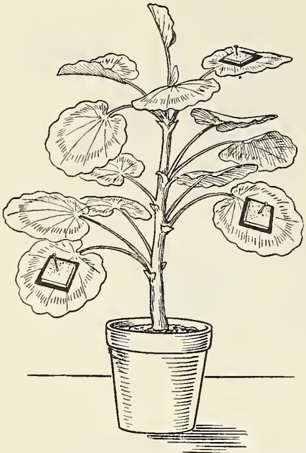
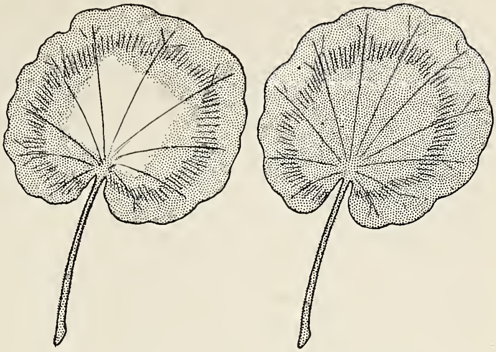


FIG. 5–1. On three of the leaves of this geranium plant, squares of cork and carbon paper have been pinned, on both sides. The plant will be left in the sunlight for several hours. Then by experiment it can be proved whether or not these three leaves will have areas in which there is no starch, and other areas in which there is much starch.

Place the geranium plant in direct sunlight, if possible, for several hours. If sunlight is not available, give the plant as much daylight as possible, and let it stand for at least two days, or use an electric arc lamp. [See Fig. 5–1.]

Now remove the leaf with the corks, together with another leaf. Take off the corks and papers, then boil the two leaves in water in a large test tube or in a beaker. After they are thoroughly softened, boil them again in alcohol. (Remember that alcohol fumes are flammable.) If a large test tube is used, fit it with a rubber cork and a piece of glass tubing at least eight inches long. If the leaves are boiled in a beaker, use a piece of wire screening under the beaker and keep the gas flame rather low. The alcohol will dissolve the chlorophyll and will become bright green. After the leaves have become pale, pour off the alcohol and rinse the leaves in water. Now remove the leaves, and place each leaf in a Petri dish or a saucer. Pour over them some tincture of iodine and leave them for a few minutes. Then pour off the iodine, wash them again with water, and spread each leaf on a glass plate. If the experiment was carefully performed, you will see the uncovered part of the leaf on which the corks were placed, and all the second leaf, colored bluish-black. The parts covered

FIG. 5–2. If you performed the experiment on starchmaking in leaves, you should be able to tell why there is a light-colored square in the leaf A, and why the rest of that leaf and all of leaf B are dark.




by the corks will be pale yellowish from the iodine stain, but otherwise uncolored.

What color did you expect to find in the place where the corks were? [See Fig. 5–2.]

**134. What is the explanation for the results of the preceding experiment?** Light and chlorophyll together can make starch. And the only materials needed are common water and carbon dioxide – the gas which is formed by fires and given off by animals when they breathe. Thus you find that parts of the leaf that have been exposed to strong light have produced starch, as was proved by the bluish color. But wherever the light was prevented by the corks from reaching the leaf, no starch was produced. If the leaves had not been boiled in alcohol to remove the chlorophyll, you would not have been able to recognize any bluish color on account of the dense layers of green chlorophyll.

The chemical actions involved in starchmaking are very complex and scientists do not all agree as to what takes place. However, most biologists think that the chlorophyll, by means of the energy derived from the sun, first makes a substance called *formaldehyde*. The formaldehyde then forms starch and water. Other scientists think that under some conditions, glucose sugar is formed first from the formaldehyde. Then the glucose sugar forms starch and water.

The chlorophyll is not affected by the process. There is just as much at the end of the process as at the beginning. Chlorophyll causes chemical changes in other substances without itself being changed. Such a substance is called a *catalyst.* As you learned last year, the *enzymes* in the digestive fluids are true catalysts. Yeast, which breaks down sugar into alcohol and carbon dioxide, is also a catalyst.

135. **Do green plants help to supply oxygen?** If we put some water plants such as Elodea or Sagittaria in water in the direct sunlight, bubbles will soon begin to pass off into the water from the ends and sides of the leaves. What gas do you think this might be?

By setting up an experiment, we can test this gas. Place some of the water plant in a tall jar of water. Lower over it a funnel with a short stem and support it above the bottom of the jar. Now fill a test tube with water, place your thumb over the open end, invert the test tube, put it into the water, remove your thumb and then put the test tube over the stem of the funnel. Support the tube with a clamp attached to a ring stand. Place the jar in the sunlight. Soon bubbles begin to rise from the water plant. Rising, they will be caught in the tube, forcing the water downward. As soon as an inch or two of gas has been obtained, the glass tube can be lifted off the funnel and the open end corked under the water.

You will recall from your previous science instruction that the test for oxygen is to see if it will cause a glowing splinter to burst into a flame. Light one end of a splint of wood, blow out the flame, remove the upper cork, and lower the glowing splint into the gas in the tube. The results should speak for themselves. It might be well to have a control experiment set up similar to the original, except that no plant is used. This would prove whether or not the oxygen bubbles came from the water or from the plant.

Thus we see that this water plant gives off oxygen in sunlight. Scientists have found that all green plants, during the daylight, are passing off oxygen into the air or into water.

*136. **Is carbon dioxide essential for starchmaking?** We can experiment to show that carbon dioxide is essential for starchmaking. This is not an easy experiment to perform, yet it is not too difficult to accomplish.

Obtain two small but vigorous potted geranium plants. Keep them in the dark until the starch test shows no starch in the leaves. Twenty-four hours should suffice. Then place one plant in water in a saucer or soup plate. Put the saucer and plant in a pan into which about a pint of limewater has been poured. Do not let the limewater come up into the saucer or soup plate. Now cover the saucer and plant with a bell jar which is immersed in the limewater. Do the same thing for the second plant, but pour an equal amount of water, instead of limewater, into the pan. Carbon dioxide is absorbed by limewater which then turns milky or cloudy. If the plants are left in the dark for 24 hours or longer, how do you think the air in each bell jar would be changed? Now carefully take both plants out of the dark and place in direct sunlight for several hours. Then remove the bell jars and test a leaf from each plant (mark one of the leaves in some way to identify it) for the presence or absence of starch. Are the results what you expected? [See Fig. 5–3.]

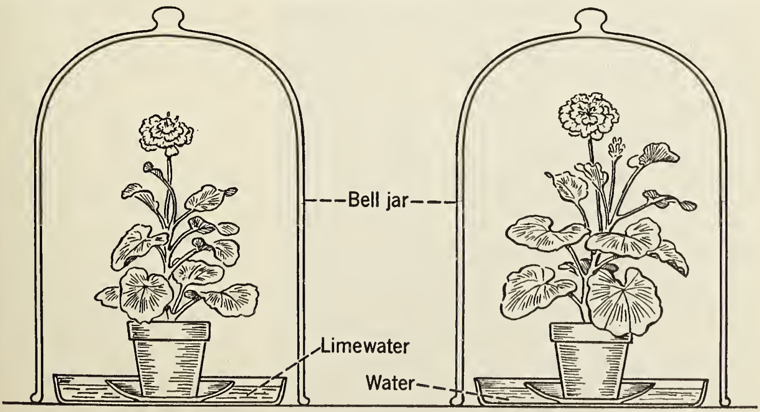



Fig. 5–3. How does this experiment prove what kind of gas is given off by green water plants?

**137. How is the green plant adapted for starchmaking?** First of all, a green plant must have chlorophyll. This substance is rapidly manufactured by leaf cells and by the cells of the middle bark whenever there is a strong light. In order to get more light on the leaf cells, the blade of the leaf in most plants is broad, or at least exposes a good deal of surface to the light. The arrangement of leaves on the stem and the growth of twigs and branches bring as many leaves as possible into the light. Look at a maple tree or a lilac bush in the summer time, and see how the leaves get all the light possible. In a forest it is difficult for young trees to get as much light as they need. Evergreens frequently show few live branches for a considerable height above the ground. The lower branches have died for lack of light. [See Fig. 5–4.]

The two materials out of which starch is made are water and carbon dioxide. You already know the path of ascending water from the roots into the ducts of the stem, and then through

FIG. 5–4. Notice the distance from the ground at which some branches of these sequoias grow. What may have made it possible for branches on some of the younger trees to grow nearer to the ground? How much light do you suppose it takes to grow trees as enormous as the one which has been felled? (*Courtesy Sequoia and General Grant National Park*)

the veins of the leaf out into the spaces between the spongy cells, from which the palisade cells can absorb it as needed.

The carbon dioxide comes into the leaf in the air entering through millions of little stomata in the lower epidermis. There is not much carbon dioxide in the atmosphere; only about 3 parts in 10,000 parts of air. Yet there is sufficient to provide all the carbon needed to make *carbohydrates*.

**138. Does starchmaking go on only in the light?** Plants tested late in the day when the sun has been shining show the presence of starch. If the same plant be tested early in the following day, little or no starch will be found. By experimental research, scientists have found out that (a) chlorophyll is formed only in light; (b) chlorophyll cannot make starch except in the presence of light; (c) starch is changed into sugar and taken out of the leaves in darkness.

**139. Can starchmaking in a green plant be likened to a factory?** The following comparison may be made between a green plant and a factory.

The Green Plant as a Carbohydrate Factory

| | |
|---|---|
| The factory | Green leaves, green bark (or other green tissue) |
| The workrooms | Cells of palisade and spongy layers, cells of green bark |
| The machinery | Chlorophyll |
| The energy | Sunlight |
| The raw materials | Carbon dioxide and water |
| The supply department | Root hairs, stomata, air spaces |
| The transportation department | Ducts, veins, sieve tubes |
| The delivery department | Rays carrying digested food |
| The finished products | Sugar and starch |
| The waste product | Oxygen |
| The hours of work | Manufacturing department, sunrise to sunset<br>Supply and transportation departments, continuously, twenty-four hours a day |

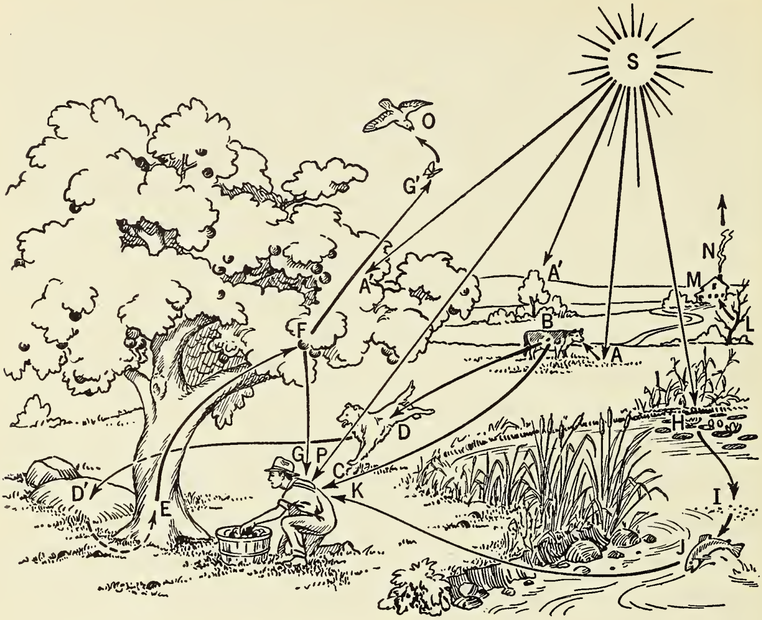



FIG. 5–5. Energy cycle. The sun (S) is the source of our available physical energy. Its light rays produce carbohydrates in grass (A), in tree leaves ($A^1$), and in water plants (H). These rays also produce vitamin D in the skin of the man (P) and in the milk of the cow (B). The cow eats the grass, and transforms it into muscle, fat, and other tissue, which man (C) eats as meat, thus obtaining such necessary nutrients as protein and fat. The dog (D) also eats meat which is changed into tissue. When the dog dies, its buried body (D′) is decayed by bacteria into chemical compounds which are used by plants such as the apple tree (E) for making leaves and fruits (F). The man (G) and the insect larva—adult form (G′)—eat fruit for assimilation or oxidation. The bird (O) eats the insect. In the water, green plants (H) are eaten by crustaceans (I), which, in turn, are eaten by fish (J). The man (K) gets protein, fats, and vitamins by eating the fish. Dead trees (L) are burned in the house (M), and a gas (N) necessary for the making of carbohydrates escapes into the air. The same gas is given off by each of the seven kinds of animals found in the picture. What is this gas? Do you think that animals are dependent upon plants? Are plants in any way dependent upon animals?

**140. How does photosynthesis store up energy in the plant?** Light is a form of energy which comes from the sun. Chlorophyll absorbs this light and transforms it into inactive, or potential, energy in the form of carbohydrates. That there is energy in carbohydrates is evident when that energy is released by the combining of carbohydrates and oxygen in the cells of a living organism. If the carbohydrate is oxidized it produces heat or energy for doing some kind of work. If the carbohydrates were burned in an engine, the heat released would be equivalent to the amount of light energy absorbed in the process of photosynthesis when the carbohydrates were formed. If the carbohydrates have been changed by the plant to other nutrients and then transformed into wood, bark, or leaves, the law still holds. So, when wood is burned in a fire, the amount of energy released in the form of heat is about the same amount as that used in making the wood. In one sense, then, it is correct to speak of wood and coal (which is made from plants) as "imprisoned sunlight."

In fact, all the physical energy seen in the activities of plants and animals can be indirectly traced back to the energy of sunlight captured and stored during *photosynthesis.* [See Fig. 5–5.]

**141. What nutrients other than carbohydrates do green leaves produce?** The soil water that comes into plants always has more or less mineral substances in it. Some of these substances are compounds containing sulfur, compounds containing nitrogen, and compounds containing phosphorus.

The protoplasm of the leaf cells of green leaves is able to combine these mineral substances with the carbohydrates of its own manufacture, and produce nutrients such as protein (containing carbon, hydrogen, oxygen, nitrogen, sulfur, and usually phosphorus), and oils (always containing carbon, hydrogen, and oxygen).

As you know, animals require carbohydrates, proteins, and

oils in their food. Yet none of our common animals can make food out of chemical substances as can green plants. There are a few small animals such as microscopic Euglena which have chlorophyll and which can manufacture food like a green plant.

Green plants are the basic source of most of the vitamins so essential to animal growth and health. Some of the plant enzymes when eaten by man are very beneficial.

**142. Is water necessary to a plant?** As you have just learned, water is necessary for the making of carbohydrates in the process of photosynthesis.

Water is also necessary both in the making of protoplasm and for the continuance of the life of protoplasm. From 70 to 80 per cent of the protoplasm of plant cells is nothing but water.

Since plants have no large openings like the mouths of animals, mineral matter and other solid substances will enter the plant only if they are dissolved in the water that is absorbed by the roots. Probably some carbon dioxide also is dissolved in water before it enters the leaf cells. Water is necessary to keep the absorbing membranes of cells moist throughout the plant.

Water again is necessary for the carrying of various substances through the plants in the ducts, sieve tubes, rays and veins of leaves.

It is also essential for producing *rigidity* in plants. By osmosis, water is taken into cells which increase somewhat in size and thus make leaves and stems stiffer, like a soft balloon which becomes harder when fully blown up with air.

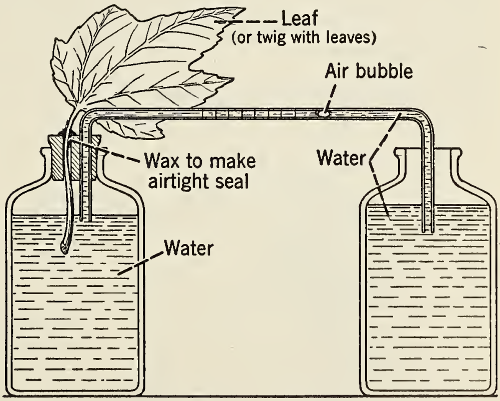
Finally the changes involved in growth and reproduction take place only when there is sufficient water. Water, then, is essential for the physical and chemical changes and activities within the plant.

**143. What does the plant do with excess water taken in by the roots?** All plants take in more water than they can use in starchmaking. It takes a great deal of water to get

enough material matter to make proteins and fats. The process is much like a hungry man eating thin soup. He would have to consume a good deal to get enough nourishment if soup was all he had to eat. The excess water taken in by the plant has to be got rid of. This is done through the stomate openings. The water passes off into the air as invisible vapor. Because we do not see this moisture, it is difficult to realize the tremendous amounts of water constantly being given off into the atmosphere from living plants. It is said that the water given off by wheat during its period of growth in a field, would be sufficient to cover that field to a depth of 4 or 5 inches. It has been estimated that an acre of corn during one growing season transpires 700,000 quarts of water besides requiring 4,500 additional quarts of water for photosynthesis.

**144. Can we experiment to show transpiration?** An interesting experiment can be set up as illustrated in Figure 5–6. Make sure that there are no leaks, especially around the petiole of the leaf. If necessary use vaseline around the

FIG. 5–6. By setting up an experiment as suggested in this diagram, the rate of transpiration can be demonstrated, also the effect upon transpiration of various conditions of the air.




petiole. After the bottles and the glass tube have been filled with water, slightly raise the free end and allow an air bubble to enter this end of the tube. Immediately immerse again in water. Repeat as often as necessary. Place

the apparatus in the sun and note any movement of the air bubble. Evidently the water is moving through the tube. What causes such a movement? Does fanning the leaf (making an artificial wind) make any difference in the rate of movement of the bubble? Cover the leaf with a little bag. Does this cause any effect on the rate of movement of the bubble? Can you explain these different results?

**145. What does the plant do with the nutrients it produces?** Since plants are composed of living cells, they require food as do animals and for nearly the same reasons. An essential difference between green plants and most animals is that these plants, by the aid of light, can make their own food if they have sufficient water and carbon dioxide. Animals which cannot do this are utterly dependent upon plants.

In order to use this food, it must be altered, as in the bodies of animals, by digestive enzymes. Undigested starch will not pass through cell walls, but it will do so when digested to a form of sugar. Plants change the starch to sugar, usually by an enzyme called *diastase* (dī′ȧ·stās), for transportation through the plant and for entrance into storage cells of the root or stem. There it may be changed back again into starch. Therefore, when you eat a potato, you are

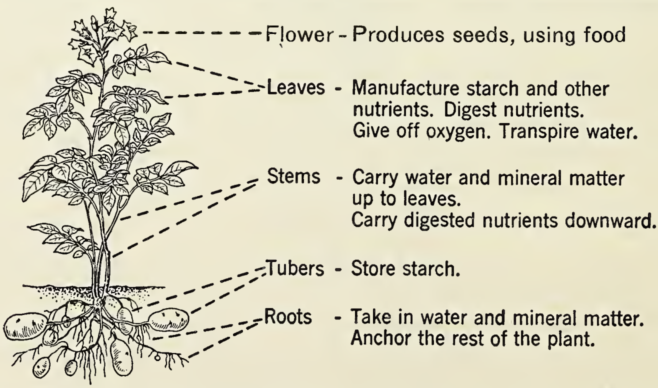



Fig. 5–7. All parts of this potato plant share in the vital functions carried on by every green plant.

eating starch produced first in the leaves of the plant, then changed into sugar, brought down into the underground stems called tubers and there changed back again into starch for storage. Proteins and oils are also digested by special enzymes. They, together with starch, are commonly stored in seeds. [See Fig. 5–7.]

Nutrients are used by plants, as by animals, for making protoplasm and repairing cells — a process called *assimilation* — and for releasing energy through combination with oxygen — called *oxidation*. To be sure, the plant is inactive compared with most animals, hence relatively little oxidation occurs in plants. As you know, animals depend upon plants, directly or indirectly, for nourishment. Sometimes it may seem as though plants are being robbed by animals.

Every living cell in a plant requires oxygen. This life-sustaining gas enters the plant largely through the stomata in the leaves, and also to some extent through the lenticels in the bark. It is probable that a considerable quantity of oxygen is dissolved in the soil water taken in by the roots.

One of the results of oxidation in plants, as in animals, is the formation of waste substances. You all know that carbon dioxide is given off in the exhaled breath of animals. It is produced, too, by all the living cells of plants, but it is doubtful whether much of this carbon dioxide reaches the air outside of the plant, except at night. Carbon dioxide is so essential to starchmaking that during the daylight it is probably immediately consumed by the leaf cells in the process of photosynthesis. When starchmaking ceases, then there is probably a small but steady intake of oxygen and outgo of carbon dioxide from a green plant.

***146. What substances other than food are made by plants?** Many of the most important materials and compounds used by man are manufactured by plants. Most of them seem to have little value to the plant itself.

Among such substances can be mentioned various oils which give odors to flowers and so-called flavors to fruits and

Fig. 5–8. The bark of several kinds of trees, including hemlock and oak, is used by man in tanning leather. Here is a pile of tanbark from hemlock trees. (*U. S. Forest Service Photo*)

vegetables. Some of these oils are camphor, vanilla, mint, lavender, and menthol. Various stimulants, narcotics, and medicines, are also obtained by man from plants. These include caffeine from coffee and theine from tea, opium from the poppy, strychnine from the strychnos tree, cocaine from coca leaves, nicotine from tobacco, quinine from cinchona, atropin from deadly nightshade, and many others. The bark of the hemlock, oak, and other trees contains substances called *tannins* by which man changes hides into leather in a process called tanning. [See Fig. 5–8.] Resins and gums are made by certain plants, especially the evergreen trees. In some plants like the milkweed, fig, and rubber tree, a milky fluid called *latex* is produced. This latex, when converted into rubber, has become one of the most valuable materials of the civilized world. Experiments are being conducted in the cultivation of plants such as *guayule* (gwä·yōō′lā), from which to obtain rubber substitutes.

*147. **To what extent can scientists make nutrients in the laboratory without chlorophyll?** It is a very simple matter to extract chlorophyll from leaves, as you found out in one of the experiments just performed. Doubtless you have wondered if clever scientists could not take this chlorophyll and use it to make starch. However, extracted chlorophyll is no longer alive, and dead chlorophyll will not manufacture nutrients.

By painstaking experiments a small amount of fat has been produced from chemicals, and, possibly, at some future time other nutrients will thus be made in chemical laboratories. It is doubtful, however, that such means, costly in money and time, will ever seriously compete with nature's method of producing food for the world by means of green plants.

## *Questions*

1. What can a green plant do that animals cannot accomplish?
2. How can plants that are not green, such as white mushrooms, get needed food?
3. Can you describe experiments that prove: (*a*) that starch is made in green leaves with the aid of sunlight; (*b*) that no starch is made in green leaves in darkness; (*c*) that carbon dioxide is an essential substance for the making of starch; (*d*) that oxygen is given off as a by-product of starchmaking.
4. What are the substances out of which plants make nutrients?
5. Why is it necessary frequently to put fresh fertilizer on the garden?
6. Name several ways in which the carbon dioxide which plants require gets into the air.
7. Can you see any basis for the belief sometimes expressed that plants spoil the air and therefore should be taken out of a room where there is a sick person?
8. Why is it safer for the plant to store its manufactured carbohydrates in the form of starch than in the form of sugar?

9. Can you trace the course of a particle of digested starch from the cells of a leaf to the storage cells in the center of the stem and the root?

10. What happens to the quantities of moisture given off from plants by transpiration?

11. Is the air in a forest likely to be dry or moist? Can you explain?

12. For what different uses is water necessary in a living plant?

13. Can you explain how light energy from the sun is conserved in the plant by means of photosynthesis?

14. What is a balanced aquarium? What water plants should be selected for such an aquarium?

15. Can you list some important substances other than nutrients that are produced by plants?

## *Some things for you to do*

1. Read about the breaking down of chlorophyll and the formation of reds and yellows in the autumn foliage of trees. Write a short article on "The Colors of Tree Leaves in Autumn."

2. Use colored glasses in such a way that several geranium plants will each be lighted by a different color. Find which colors of the spectrum help and which colors hinder the making of starch in the leaves of these plants.

3. Set up a balanced aquarium in your home or at school.

4. Find some interesting facts about catalysts and their uses, in an encyclopedia or other reference book. Write a report on what you have read.

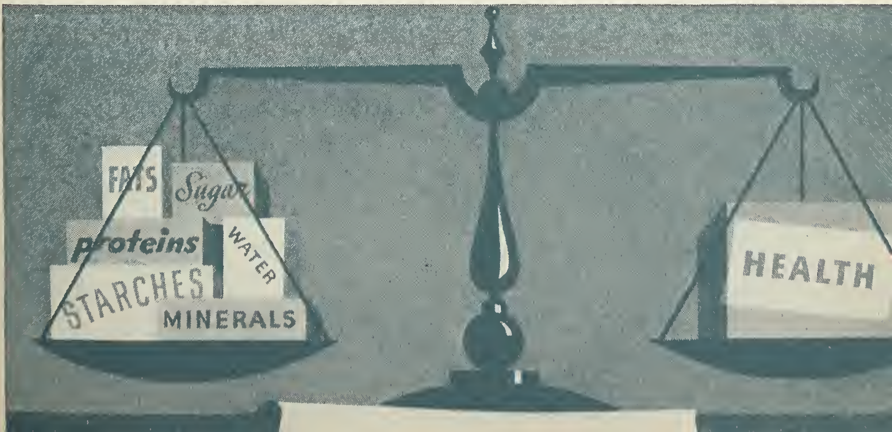
5. Measure the amount of water transpired by a geranium plant during 48 hours. Select a vigorous potted plant which has been kept well watered. Cover the pot with rubber sheeting. Place the plant, together with an empty beaker or glass, on one scale pan of a balance. Balance the other arm by adding weights. At the end of 24 hours, add enough water to the glass to balance the plant. Do so again at the end of 48 hours. Measure the amount of water in the glass. What does this represent?

# Scientists Are Finding More Healthful Diets for Us

MAN became acquainted with the massive parts of the universe before he became acquainted with the very small parts. He invented the telescope before he invented the microscope, and discovered many facts about the planets before he discovered what a vitamin is.

But within the last twenty-five years, scientists have set themselves seriously to work on research concerning food. White rats and other animals have been used extensively in such research, especially in experiments with vitamins. By such means, certain facts have been established about the values to human beings of different kinds of food: the importance of nutrients, the meaning of balanced diets, variations in diet for different individuals, and the absolute necessity of vitamins for normal development and the maintenance of health.

This scientific information has been spread widely through magazine and newspaper articles, lectures, books, and the



radio. In an effort to take commercial advantage of those who read or hear about this new information, impostors have advanced fraudulent or exaggerated claims for supposed foods and remedies. To discriminate between the genuine and the fraudulent in such substances requires great care and intelligent information on the part of the consumer.

The first chapter in this unit makes a survey of nutrients which keep human beings alive; the second chapter tells about the vitamins which scientists have found necessary to keep human beings healthy.

## *Think about these!*

1. What is the relation between diet and health? Diet and wealth?
2. Why do radio programs advertise foods or diets?
3. What sort of diet should a growing child follow to ensure having a sound body?
4. What is the most nearly perfect food?

## *Words for this chapter*

**Entrails** (ĕn′trālz). The internal organs of an animal, especially the intestines.

**Microorganisms** (mī′krȯ·ôr′gă̆n·ĭz′mz). Minute living creatures, usually consisting of only one cell.

**Desiccated** (dĕs′ĭ·kāt′ĕd). Dried.

**Adulteration.** Rendering a substance impure, or dangerous to the consumer, through the substitution of inferior substances, the omission of important ingredients, or the addition of injurious substances.

*CHAPTER 6 — UNIT 3*

# *Why Do Our Bodies Need Nutrients?*

**148. Why do you get hungry?** Why is it more difficult to pay attention to uninteresting work in the period just before lunch? The answer is easy. If you are a normally active boy or girl you have to compete with increasing hunger. Just what is hunger and when do you feel the hungriest? Professor Cannon of Harvard University has shown conclusively that hunger is a definite sensation caused by wavelike contractions in the wall of the stomach when the body needs food, or at the time when it is accustomed to receiving food. Thirst, likewise, is a sensation produced by dryness of the throat and of the back part of the mouth.

***149. How often do animals eat?** Most persons eat three times a day, although some have four meals and others only two. Wild creatures do not have special times for meals. They search for food when they are hungry, and when food is found, they eat until they are satisfied, if that is possible. A toad may eat almost continuously all through the night. Some animals can go a long time without food. A snake may

swallow a rat and then not eat for weeks. A regal python when first brought to the New York Zoological park in New York City went on a hunger strike for a period of just a few days short of two years. The python was then forcibly fed. Certain beetles have retained life without food for approximately five years. The record set by a human being for going without food is a little over forty days. Yet whether much or little food is consumed, sooner or later the demands of hunger must be met or the individual dies.

*150. **What foods are eaten by animals other than man?** There are many animals such as wood-boring beetles, termites, and porcupines that subsist on wood, either wholly or in part. Animals like the cow, sheep, and deer live on grass. Most animals of the sea and many animals of the land feed upon other animal forms which they capture for food. It is a fair statement to say that animals live either on plants or other animals, or eat both plants and animals.

151. **What kinds of food are eaten by human beings?** Most persons are accustomed to eating foods such as milk, meat, potatoes and other vegetables, fruits, bread, butter, fish, cheese and so on. However, many things that seem strange or even revolting to us are eaten by different races in the world. If you had been born an Arab in northern Africa, you would probably relish grasshoppers fried in oil. One of the greatest delicacies a Chinese can eat is bird's-nest soup made out of gelatinous secretions of certain birds; these birds make their nests from this material. In many parts of Africa, feasting natives devour practically every part of a roast ox, including the *entrails.* Stefansson, the Arctic explorer, says that the Eskimos with whom he stayed were accustomed to eat all parts of a fish except the bones and scales; and if the fish was somewhat decayed, they liked it much better. In some places termites are considered a delicacy. Perhaps the strangest diet of all is clay, which is eaten by certain mountain folk in the Appalachian Mountains, though to the detriment of their health.

**152. Why does the body need food?** If different animals and individual humans eat such varied things, the question might well be asked whether it really matters what a person eats. Can the research of scientists tell us whether certain substances are better for us than are others? Are there diets that really make a difference in maintaining health and producing a longer life?

These questions can be answered more satisfactorily when we understand why the body needs food.

You have already learned that material that can be used for repair and growth must be furnished to the cells. Let us call this the building material of the body. In addition, the body must have material that can be oxidized and thus furnish heat and physical energy.

Insects may be able to get building material and fuel from wood, and cows and horses may get similar materials from grass, the walls of whose cells are made of *cellulose.* Yet mankind cannot digest the cellulose parts of either wood or hay. Human beings then are dependent on nutrient ma-

Fig. 6–1. Meals which are attractively served aid digestion. (*Courtesy Armour & Co.*)

terials that their body cells *can* utilize. There are still other substances, not used for cell building or for oxidation, that the human body must have for good health. These are called *vitamins.* They will be discussed in more detail in the next chapter. Since cultured persons enjoy pleasant odors and flavors and the attractive appearance of good food, the importance of these matters should also be recognized if the utmost value of good food is to be realized. Pleasurable feelings at meal time induce the secretion of digestive juices, so that the way food is prepared is sometimes as important as the food itself. [See Fig. 6–1.]

**153. What is food?** Food, then, is any substance which, taken into the body, furnishes material for cell building or for oxidation. Food also should include the necessary vitamins. Rarely does any food consist solely of the materials just mentioned. Most foods contain a considerable amount of material that cannot be used by the body. Since this matter is refused by the body, it forms the bulk of the refuse, or waste, which is finally expelled from the alimentary canal. True body waste, however, is the result of oxidation in the cells. Also in certain vegetables such as celery, lettuce, potato skins, and others, there is quite a bulk of cellulose material which composed the cell walls of the plants. This material, although commonly eaten, is indigestible in the human body. However, it is important in the diet, as "roughage." [See Fig. 6–2.] This gives the intestinal muscles exercise in pushing the food along through the alimentary canal.

**154. What is a nutrient?** Through experimentation, biologists found and isolated several kinds of true food substances, to each of which they gave the name *nutrient.* To the nutrient primarily used in all cell building they gave the name *protein. Mineral matter* is another nutrient, used principally in building bones and teeth. *Water* is perhaps as important as a nutrient as any, because two-thirds of the body is nothing but water, and the body requires more intake of water than of any other nutrient. The name *carbohydrate*

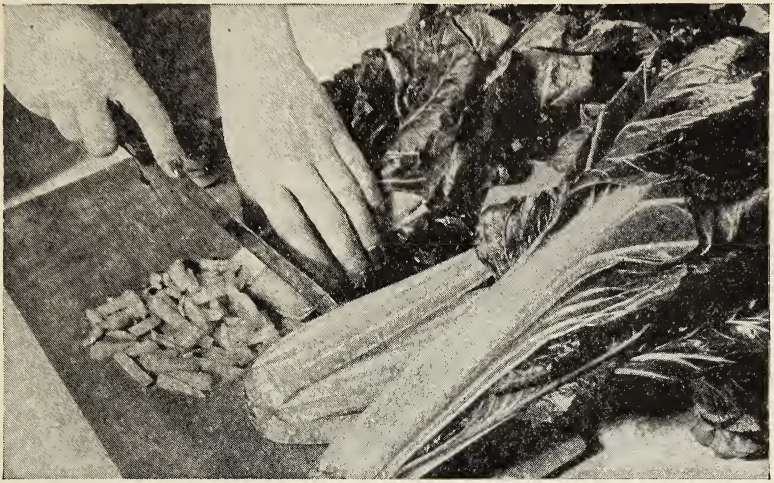


FIG. 6–2. Swiss chard is an important leafy vegetable that grows easily, and is an excellent source of important minerals. (*Courtesy "Journal of Living"*)

was given to *starches* and *sugars* because these nutrients consist only of the elements carbon, hydrogen, and oxygen — the hydrogen and oxygen in the proportions found in water. Carbohydrates are very valuable as fuel for the body. The most important body fuel, however, is another nutrient, *fat*. Milk is the most nearly perfect food since it contains all the nutrients, though it is somewhat lacking in carbohydrates.

There are hundreds of kinds of foods, but there are only six nutrients, one or more of which should be in any substance if it is to be regarded as a true food.

In addition to the nutrients, good health demands that our food contain the proper amount of vitamins. From experimental evidence about 15 kinds of vitamins have been discovered, each of which is essential in our daily diet.

**155. Carbohydrates, our cheapest fuel food.** Starch and sugar are made in green plants. We therefore rarely find these nutrients in the flesh of animals, though a small amount of an animal starch called *glycogen* (glī′kō·jĕn) may be found in the liver and muscles. Practically all parts of plants eaten

for food contain carbohydrates. Starch is concentrated in the form of cornstarch, grains, vegetables, flour, tapioca, and other substances. Besides the white and brown sugar, the nutrient sugar is eaten in the form of candy, honey, dates, ripe fruit, and other foods. Starch and sugar contain the same elements in slightly different proportions. When eaten, they are both changed into the same substance in the body. If a person refrains from candy in order to reduce his or her weight, but eats plentifully of potato, bread, macaroni, and rice pudding, for example, the benefit in the first plan will be neutralized by the excess of the second. [See Fig. 6–3.]

Carbohydrates are fuel foods. This fact is recognized by explorers, athletes, and soldiers. Sugar and chocolate are used to furnish energy for forced marches and for exertion of various kinds. Too much carbohydrate consumption is likely to produce fat and may be a factor in the disease known as diabetes. Too little carbohydrates in the diet will result

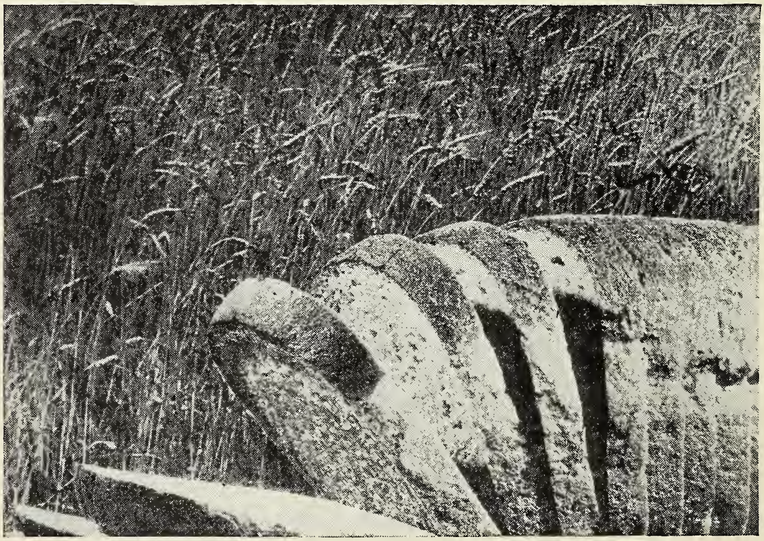


Fig. 6–3. Wheat is the staple food of millions of people. Whole-grain wheat products provide vitamins and minerals. (*Courtesy General Mills, Inc.*)

in the oxidation of the reserve fat and some of the protein in the body, tending to cause a person to lose weight.

**156. How can we test for the presence of starch?** Put in a test tube as much starch as can be piled on a ten-cent piece. Add water until the test tube is half full, and shake the tube thoroughly. Wipe the outside of the test tube dry, then boil the mixture over a flame (Bunsen or alcohol burner), taking care that the test tube is moved about to heat different portions evenly.

Now add a small portion of this starch paste to a test tube of clear water and shake. With a medicine dropper place one or two drops of a tincture of iodine in the top of this test tube of starch and water. Note the color formation of a deep blue. Shake to get a uniform color. Hold up to the light. If a substance is tested in this manner for the presence or absence of starch and this blue color appears, you may be sure that starch is present.

**157. How can we test for the presence of sugar (grape sugar)?** Dissolve some brown sugar or molasses in half a test tube of water, and add several drops of either Fehling solution or Benedict's solution. Gently heat the mixture. As it becomes hotter, look for a greenish color quickly changing to brown, then brick red. This brick red color should appear whenever this test is used *if* grape sugar is present in the substance tested. White sugar does not produce this striking color reaction.

**158. Where do we find protein?** Proteins are contained in some plant foods and in most animal foods. The white of an egg, for instance, is almost entirely a form of pure protein called *albumen* (ăl·bū′mĕn), together with some water. Protein constitutes 13.4 per cent of the contents of an egg. Meat, fowl, and fish are almost entirely composed of water and a protein called *myosin*. The amount of protein in such foods varies from 15 per cent to 20 per cent of the substance. About 12 per cent of grain is a protein called *gluten* (glo͞o′tĕn). Beans, peas, lentils, and peanuts contain

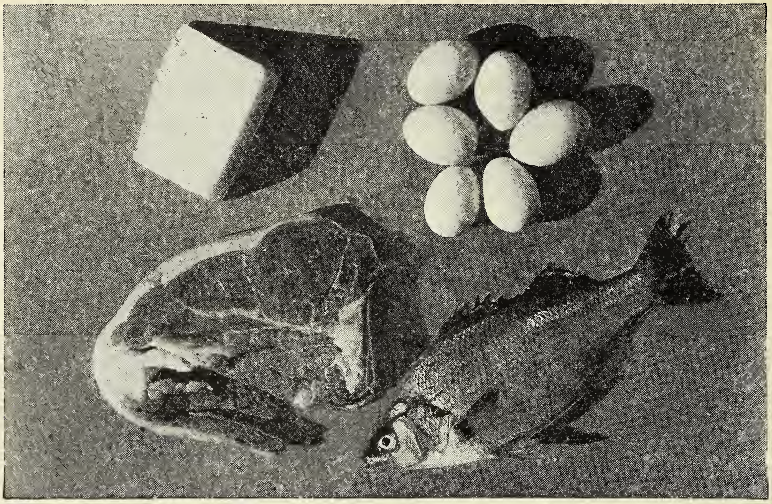


FIG. 6–4. Most animal food is high in protein content. Cheese is about 26% protein; eggs, about 14%; meat about 20%; and fish, about 18%. (*American Museum of Natural History*)

from 20 per cent to 29 per cent of protein. Cheese is equally high in a special protein called *casein* (kā′sē·ĭn). [See Fig. 6–4.]

Protein contains the four most important elements found in protoplasm, also several others, namely: carbon (about 40 per cent), oxygen (about 36 per cent), nitrogen (about 16 per cent), and hydrogen (about 8 per cent), also usually phosphorus and sulfur (very small amounts), and sometimes iodine, zinc, copper, and manganese (traces). Is there not some simpler way to get the elements needed for body building than to eat protein? For instance, the atmosphere is an enormous ocean of air, four-fifths of which is nitrogen gas and about one-fifth oxygen gas. Why can we not breathe in air, and thus supply the oxygen and nitrogen needed by the body for cell building in this simple way? No one knows exactly why the body cannot utilize these elements in their free form, but every boy knows that taking in a breath of air does not produce the same comfortable effect as taking in

protein food. Similarly, it would seem a very simple matter to eat sufficient quantities of charcoal, a very cheap form of almost pure carbon, in order to obtain the carbon needed for cell construction. Yet, charcoal, if eaten, will be ejected from the body unchanged.

Proteins alone seem to furnish the primary elements the body needs, in such chemical combinations that the body can utilize them for growth and repair.

You can eat protein foods, and without special thought from you, they are changed over into parts of your body. In fact, much of this repair and growth of the body takes place at night when you are fast asleep and know nothing about it.

Proteins can be oxidized in the body in the absence of sufficient carbohydrates or fat, or if excess protein is eaten. But the wastes from proteins are more dangerous than those from other nutrients. Too much protein overtaxes the kidneys; too little causes weakness and low blood pressure.

**159. What are the tests for protein?** Take some protein, such as white of egg, or albumen. (*a*) Heat it in a test tube or spoon until it thickens. Liquid protein thickens, or coagulates, when heated. This will also be seen when milk is heated. The scum that continually forms is largely protein. (*b*) Second, to this coagulated egg in a test tube, add a little strong nitric acid. (Caution: Pupils should not handle strong acids. Your teacher will probably help you make this test.) You will see that the white of the egg turns yellow. Heating makes the color stronger. If the nitric acid is now washed off and aqua ammonia added, the color changes to orange. When you are testing a substance in this manner, such color changes indicate the presence of protein. (*c*) Burn a little white of egg, either raw or cooked. An odor characteristic of burning protein is given off. Concentrated protein such as skin, feathers, or finger nails produce such an odor when burned.

**160. Why do we need water?** A large per cent of the body is water. This is not a peculiar kind of water. It is the same

thing that you get when you turn on the faucet. It is the same substance that falls as rain. Yet nearly two-thirds of your body structure is nothing but this water.

Water is a basic need for the making of protoplasm. You will recall that it is one of the two necessary substances from which green plants make starch. In both plants and animals, water is also the chief means of dissolving and transporting foods and other substances through the organism. In the human body, as in the body of many other animals, water is the chief ingredient of the blood, and it is a solvent for waste matter in perspiration and in urine.

**161. How can we test to show the presence of water?** It is a simple matter to demonstrate that water is present to a large extent in plants and in animals as well. Secure two large potatoes of about the same size. Peel one and cut it into quarters. Put the unpeeled potato on the pan in a scale balance and the quartered potato on the other scale. Also put a bottle with a cork on the pan with the quartered potato and balance the scales by adding weights to the other pan. Each day add enough water to the bottle to bring the scales to balance. Can you explain why the water in the bottle represents the amount of water lost by the quartered potato? Why should the bottle be corked? What changes in size and shape are noticeable in the cut potato? Why does the unpeeled potato not change within ten days?

**162. What is the source of fats and oils?** Fat and oil are essentially the same thing. This fact can be observed by warming butter until it melts. Fat which is swallowed is sooner or later melted by the body heat before digestion takes place.

Fat consists of a large proportion of carbon and hydrogen combined with oxygen. It is obtained from animals as a part of almost all meats; from the flesh of certain fish, such as salmon and mackerel; and from the livers of cod and halibut. It is also found in cream, butter, cheese, and the yolk of egg. Oils are present in the olive, lemon, and banana;


FIG. 6–5. Solid fruits and vegetables are less solid than they seem. A banana is 75% water. One of the melons in this picture would contain even more water. (*Courtesy "Journal of Living"*)

in cotton seeds, castor-oil seeds, and peanuts. [See Fig. 6–5.]

Fat is a very important fuel nutrient for the body, giving somewhat more than twice as much energy per unit of quantity as given by carbohydrates. If it were advertised as a gasoline is, the claim would be made that it gives more "mileage" than carbohydrates. Fat is easily retained in the body. A certain amount of stored fat produces a well-fashioned body and gives the appearance of health. It is valuable as a sort of insulator against cold and the loss of heat from the body in cold climates. Too much fat in a person's diet usually results in that person's having ample bodily proportions and being regarded as "fat." There are, however, other causes for overweight such as disturbances of the ductless glands. Too little fat in the diet tends to cause loss of weight.

163. **How can we test for fat?** Put a drop or two of some oil on a piece of absorbent paper and rub it to form a spot about the size of a quarter of a dollar. With clear water, make a spot of the same size on another paper. Now place both papers in a warm place. Examine in a few minutes. The water will have disappeared but the oil spot will persist. Thus, the test for oil is to rub a piece of soft paper with the substance and see if an oily spot remains.

Another way of testing for the presence of oil is to crush the substance to be tested. Then add a small amount of

ether, benzol, or carbon tetrachloride, and stir it. (Caution: Do not use ether or benzol solvent near a flame.) After a few minutes pour off the liquid into a shallow plate. Very soon the liquid will have evaporated, leaving whatever oil there may be on the plate.

**164. What is mineral matter?** In addition to the elements carbon, oxygen, hydrogen, and nitrogen, there are fourteen other elements used by the body. These come into the body as compounds called *salts*, which constitute the mineral matter of food. Calcium and phosphorus are important for making bones and nerves. Compounds of iron and copper are necessary for the work of the red blood cells. Certain salts of sodium, potassium, and calcium are necessary for the proper beating of the heart. Iodine is essential for the functioning of the thyroid gland. Sulfur is a part of all protoplasm. Chlorine, as an element found in salt, is useful in nutrition. Magnesium and manganese are essential for growth and health. Silicon, fluorine, and zinc are also valuable in the body.

**165. How can one test for mineral matter?** You will recall from your study of water that the presence of mineral matter in drinking water was shown by heating the water to evaporate it. Whatever mineral matter had been present was left when the water disappeared. The common test for mineral matter in food is to burn the substance as long as any part will burn. The white ashes represent the mineral matter that was present in the food.

There is much ignorance about the sources of mineral matter, due to misleading advertisements. Raisins and spinach, for instance, do have some iron, but beans, peas, egg yolks, and liver have about three times the amount of iron found in either of these foods. Shrimps and almonds are relatively rich in copper. Blueberries, dates, and oatmeal have the most manganese. Milk, cheese, eggs, chocolate, and turnip greens furnish calcium abundantly. Beans, peas, lentils, egg yolk, almonds, walnuts, and oatmeal are particularly valuable

FIG. 6–6. What kind of country is best suited for growing wheat? Is wheat always planted at the same time wherever it is grown? (*Courtesy International Harvester Co.*)

for phosphorus. The rest of the mineral elements will be obtained in a diet including milk, fruits, vegetables, eggs, whole grain products, and some meat. [See Fig. 6–6.]

**166. What is a calorie?** As you know, carbohydrates, protein, and fat can be oxidized in the body, thus furnishing heat and physical energy. Biologists use the calorie as a unit for measuring the fuel value of a nutrient. The large calorie is the amount of heat that is required to raise the temperature of one kilogram (approximately a quart) of water 1° C. or 1.8° F. This large calorie equals 1000 small calories. The fuel value of a nutrient is expressed in calories per gram.

The energy values of the following nutrients, measured in calories, are as follows.

| | Calories per Gram | Calories per Pound |
|---|---|---|
| Carbohydrates | 4.1 calories | 1860 calories |
| Protein | 4.1 calories | 1860 calories |
| Fat | 9.3 calories | 4218 calories |

**167. How many calories are needed each day by the average man?** An average man during the course of 24 hours produces a minimum of 3000 calories, usually from 3300 to 3500 calories. This heat, if concentrated, is sufficient to warm, from freezing point to about boiling point, sixty-four pints (eight gallons) of water. In order to release 3300 calories without drawing on the body reserves, fuel nutrients to the total of somewhat more than 3000 calories must be eaten each day. Such a man will require a little less than one pound (453.6 grams) of carbohydrates, about one quarter of a pound (113.4 grams) of protein, and about one quarter of a pound (113.4 grams) of fat.

Using the proportions given in the preceding table, we get the following result:

| | |
|---|---|
| Carbohydrates .............. | 453.6 x 4.1 = 1860 |
| Protein .................... | 113.4 x 4.1 = 465 |
| Fat ........................ | 113.4 x 9.3 = 1055 |
| | Total calories ..... 3380 |

As a matter of fact, the amount of food taken into the body varies considerably from day to day. A person usually eats more after he has been exercising and also when he particularly likes the food which is served.

**168. How many calories are needed each day by boys and girls?** If a man requires somewhat over 3300 calories per day, how much does a boy or girl need? This cannot be told exactly, because some children are naturally more active than some others and therefore require more food for producing energy. Not only are there such variations due to individuality, but the calorie requirements also vary with the age, sex, occupation, and health of the individual.

In illness the factor of the disturbed condition of both mind and body changes calorie needs. In certain diseases it would be disastrous for the patient to eat anything outside a very restricted diet. In most cases the appetite is weak, and the ill person does not care for food as he does when he is

well. His lack of appetite may be due partly to the fact that his caloric requirement is usually lower in illness than in health.

The following table will give approximate daily caloric needs according to age, activity, and sex.

Daily Calorie Needs (Approximately)

| | | | |
|---|---|---|---|
| 1. | For child under 2 years | 1000 | calories |
| 2. | For child from 2 to 5 years | 1300 | " |
| 3. | For child from 6 to 9 years | 1700 | " |
| 4. | For child from 10 to 12 years, woman (not working) | 2000 | " |
| 5. | For girl from 12 to 14 years, woman (light work) | 2200 | " |
| 6. | For boy (12–14), girl (15–16), man (inactive) | 2600 | " |
| 7. | For boy (15–20), man (light work) | 3000 | " |
| 8. | For man (moderately active) | 3200 | " |
| 9. | For farmer (busy season) | 3500 to 4500 | " |
| 10. | For excavator, ditchdigger, etc. | 4000 to 5000 | " |
| 11. | For lumberman (winter) | 5000 to 8000 | " |

**169. What is a balanced diet?** There are persons with strong, varying beliefs about food. You will be sure at sometime to meet persons who will not eat any food of animal origin. They are called *vegetarians* on this account. They are likely to eat too much carbohydrate food. On the other hand there are some persons who eat meat at almost every meal. There are others who think that for the maintenance of good health you should never eat protein and carbohydrates at the same meal.

It is quite possible that certain kinds of diet may be of great benefit to some individuals, especially when prescribed by a specialist. However, we know that there are six kinds of nutrients, and eighteen kinds of elements, together with several kinds of vitamins needed for good health. These are all obtained most easily by eating the accepted foods in the right quantities. Animal foods such as meat, fish, eggs, milk, butter, and cheese, and typical plant foods such as potatoes, beans, peas, corn, and similar vegetables, bread, fruits, and leafy greens, if eaten in the proportions indicated for the average person, will furnish all of the necessary diet requirements.

One authority recommends including in the diet each day plenty of milk, some meat, fruits, leafy green vegetables, and carbohydrates.

**170. How can food be preserved?** Whatever man uses as food may also be eaten by other animals; it may be made to decay by bacteria, or it may be spoiled by molds. Civilized man has devised storehouses and special containers in which food may be kept from insects, mice, and other pests. Such treatment will not, however, prevent the entrance of bacteria, the most important agent against which food must be guarded. How man competes with these *microorganisms* will be taken up later.

**171. What is food adulteration?** In 1906 Congress passed the federal Pure Food and Drug Act, which in 1940 was amended as the Food, Drug, and Cosmetic Act. It covers standards for the preparation of foods to be canned or put up in bottles or packages. This law prevents food *adulteration* by the addition to the food of substances injurious to the consumer, or by the leaving out of important ingredients, or by the substituting of inferior materials. This law also requires that truthful statements be printed on the label naming any foreign substances used in the preparation of the contents, such as preservatives and coloring matter; and it also requires a statement of the correct weight or quantity. Substitute foods such as oleomargarine for dairy butter are permitted to be sold, but under special restrictions and standards.

The Food, Drug, and Cosmetic Act also applies to patent medicines, on the label of each bottle or package of which the contents must be stated.

Many manufacturers in following the law use very fine print for their statements of contents, or they arrange the printing on the labels so that it is almost misleading, or else they cover the bottle or package with special wrappings. However, the customer can find out what he is buying if he will insist upon knowing. It is to his best interests always to demand definite standards of quality.

## QUESTIONS

1. A man lost in the woods and suffering from hunger sometimes tightens his belt. Why might this help him for a time?
2. Why cannot man get any benefit from eating wood, although this substance is eaten by certain animals?
3. Why does the body need food?
4. Can you distinguish between a food and a nutrient?
5. How many elements are found in protoplasm?
6. How many of these elements can you name?
7. Can you test a food for the presence of (*a*) starch, (*b*) sugar, (*c*) protein, (*d*) water, (*e*) fat, (*f*) mineral matter?
8. Can you tell how each of the six nutrients is of value in the body?
9. What is a calorie?
10. If a man requires about 3300 calories daily, why can he not get these calories by eating one pound of butter, since this furnishes more than 3500 calories?
11. Why do conditions of health and age affect diet?
12. How can a customer make sure that the food he buys has not been adulterated?

## SOME THINGS FOR YOU TO DO

1. Test several food substances, as directed, for the presence or absence of starch, sugar, and mineral matter.
2. Find out about strange foods (not mentioned in the chapter) eaten by different peoples. Are there any cannibals still left on the earth?
3. Make a poster for the class, listing at the left the elements found in protoplasm. On the right give important foods containing these elements.
4. From tables furnished you by your teacher, make up the total calorie value of the three meals eaten by you during an average day.
5. Make a collection of labels on packaged foods and patent medicines to show various schemes of printing or other devices which mislead the public.

## THINK ABOUT THESE!

1. Can vitamins be got from all foods or only from certain foods, or should they be taken in the form of pills?

2. If milk were exposed to ultraviolet light coming from electric lights, would the food value of the milk to human beings be altered?

3. Do you know how white rats have saved human lives by giving us facts about vitamins?

4. Is there any relation between poor health and smoky air that prevents sunlight from reaching the earth?

## WORDS FOR THIS CHAPTER

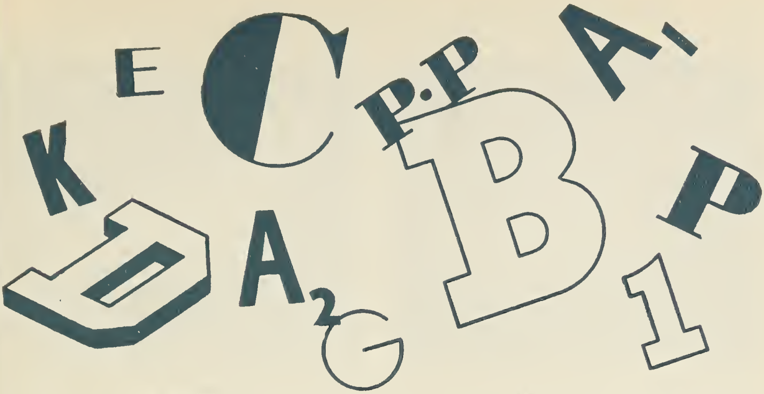
**Beriberi.** A deficiency disease due to the lack of vitamin $B_1$.

**Deficiency disease.** A disease caused by the lack of important vitamins.

**Pellagra** (pě·lā′grȧ). A deficiency disease due to the lack of vitamin P–P.

**Rickets.** A deficiency disease due to the lack of vitamin D.

**Irradiation.** Exposure to radiations of light or other rays.




*CHAPTER 7* ——————— *UNIT 3*

# *Why Are Vitamins Important for Health?*

**172. The word "vitamin."** During the past thirty years a new word *vitamin* (first called *vitamine*) has come into the English language. This word refers to mysterious substances necessary to life. The word was coined in England in 1911 by a biologist named Funk, who made use of the Latin word *vita,* meaning *life.*

***173. Who were the pioneer experimenters with vitamins?** Funk had got from rice a white powdery substance with which he cured sick pigeons. Thirteen years before this, a Hollander, named Eijkman (īk′män) had cured human patients in the East Indies of a tropical disease called *beriberi.* Eijkman simply fed his sick people whole rice instead of so-called polished rice, which they had been eating. Polished rice has had the outer skins removed from the rice kernel. Eijkman's treatment was not an accident. It was the result of scientific conclusions. Eijkman was a careful man. He had observed that chickens that ate polished rice became ill, as did the natives, but recovered on a diet which included

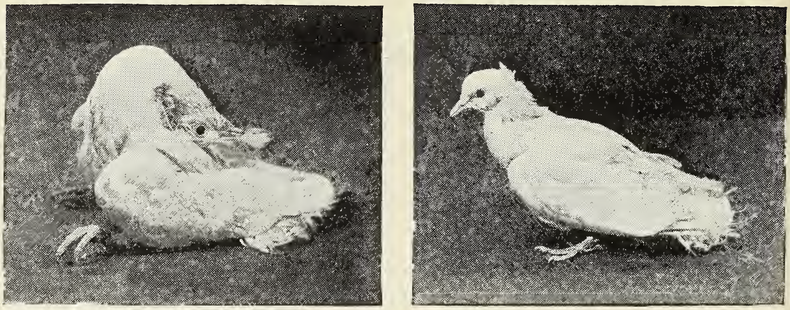


Fig. 7–1. *A.* A pigeon suffering from $B_1$ deficiency. *B.* The same pigeon cured in six hours by vitamin $B_1$ in diet. (*Courtesy The Fleischmann Laboratories*)

the outer rice skins. Evidently the whole rice was a much more complete food. It appeared also that the outer skins contained some curative substance. [Fig. 7–1.]

*174. **Discovery and isolation of vitamin B.** Following the work of these pioneers came other biologists who confirmed their work on the effects of unpolished rice. By continued experimentation, Funk finally discovered the important substance which brings about the cures. This was later called vitamin B or $B_1$. In 1935 an ounce of crystals of pure vitamin B was obtained from 20,000 pounds of the outer skins of rice by Dr. Robert R. Williams, an American investigator. This vitamin is now made in the laboratory.

175. **What is a deficiency disease?** We usually think of illness as being caused by *some thing*, such as bacteria, a poison, too much food, or a bad mental state. It is quite as possible for sickness to be caused by the absence of something. In fact, men first began to investigate vitamins because of strange illnesses which they later found were caused by the lack of important vitamins. These illnesses were called *deficiency diseases.*

For instance, sailors, for hundreds of years, had dreaded long voyages because of a strange disease which was likely to attack them. They had plenty of beef, crackers, and bread; yet their mouths became sore, their teeth sometimes dropped

out, and they bled easily. Many of the victims died. Why, no one knew. The disease was called *scurvy,* but no cure was found until someone found that if the juice of lemons or limes was included in the diet, the disease was prevented. England finally required her captains to provide this fruit on long voyages. Thus the English sailors came to be called "limeys." Modern scientists, through their biological experiments, found that in oranges, lemons, and limes there was an important vitamin which cured scurvy. It was called vitamin C. Each of us needs some of this vitamin every day, especially for the growth of strong teeth.

During the last century, another deficiency disease was attacking sailors around China and Japan and in other eastern waters. This was the beriberi referred to earlier in this chapter. Scientists have been able to cure this trouble by discovering and prescribing vitamin $B_1$. This vitamin is also of great benefit to the nervous system.

There is another well-known deficiency disease — pellagra — which has flourished in poorhouses, asylums, and prisons, and elsewhere among impoverished peoples. The discovery of the pellagra-preventive vitamin P–P, has made possible the control and extermination of pellagra.

Sometimes children's bones and teeth do not become as hard as they should. In fact, the bones may bend so that the individual does not have straight legs but is bowlegged. The teeth, also, may be soft. This condition, known as *rickets,* is usually due to the inability of the body to use calcium and phosphorus to make strong bones in the absence of sufficient vitamin D. Sunlight is the original source of this wonderful vitamin. Through extensive experimentation, biologists have found that vitamin D is produced in the skin when exposed to sunlight. They have also found out that oils exposed to ultraviolet light, by *irradiation* from electric lamps, contain vitamin D. If sunlight is not abundant, as in the winter time, then cod-liver oil or halibut-liver oil should be taken. [See Fig. 7–2.]

FIG. 7–2. Whether one goes into the ocean or not, the production of vitamin D in the body from moderate exposure to sunlight at a beach is valuable. (*Courtesy Long Island State Park Commission*)

**176. How are vitamins named?** As vitamins were discovered each was at first given a letter of the alphabet. However, investigators found that vitamin B consists of at least six different vitamins, so vitamin B always has a number (1–6) in addition to the letter. There are also vitamins $A_1$ and $A_2$. As scientists discovered the chemical substances in these vitamins, they began to abandon the simple letters and to call the different vitamins by the name of the chief chemical substance in each. Thus vitamin A is also called carotene (kăr′ō·tēn); $B_1$, thiamine (thī′*ȧ*·mēn); $B_2$, G or riboflavin (rī′bō·flā′vĭn); C, ascorbic (ȧ·skôr′bĭk) acid; and D, calciferol (kăl·sĭf′ĕr·ōl) and cholesterol (kō·lĕs′tĕr·ōl). In addition there are vitamins E, P, K, and P–P which stands for "pellagra preventive." Experiments now being conducted all over the world lead us to think that there are possibly fifteen or twenty vitamins.

**177. What are some other benefits from vitamins?** Vitamin A, now obtained chiefly from shark-liver oil, helps the vision, especially at night. It is also of great benefit in maintaining germ-resisting tissue.

*Riboflavin* and vitamin $B_6$ protect against a skin disease. Vitamin E seems to be necessary for normal reproduction in animals. Vitamin P strengthens the capillaries. Vitamin K increases the clotting power of the blood. *Pantothenic* (păn′tô·thĕn′ĭk) acid aids nutrition and tends to retard the graying of the hair.

**178. What does a pure vitamin look like?** All the vitamins just mentioned have been separated and studied in pure, chemical form. Each vitamin looks like an ordinary white, powdery substance or tiny crystals. Yet they are very powerful and in small quantities are absolutely necessary for growth and continued good health. Plants are the chief source of vitamins. [See Fig. 7–3.]

FIG. 7–3. These objects are crystals of vitamin C. The crystals have been magnified a hundred times. How do they compare with snow crystals? (*Courtesy The Fleischmann Laboratories*)

**179. How do biologists experiment to find the effects of vitamins?** White rats are among the best animals subject to use in establishing vitamin facts. In the experiments resulting in the cure for rickets by vitamin D, the general procedure is as follows. Two rats of the same sex and age are selected and put into different cages. One is given a normal diet, and the other is given a diet lacking foods containing vitamin D. In every other way the two rats receive the same treatment. Each day the rats are weighed and their weights recorded. Notes are kept as to their physical condition. As a

matter of fact, before long the rat receiving too little vitamin D will reveal faulty bone structure. Its legs will be weak and its walk will be wobbly. The X ray is used and confirms the suspicions that rickets have been induced. Now for the cure. The sick rat is given cod-liver oil or halibut-liver oil in measured amounts. He will improve every day until, finally, he will be normal again. However, the bent bones may never become entirely straight, so that as a result he may always be a somewhat bowlegged rat.

It should be noted that most experiments in vitamin study are negative rather than positive. That is to say, they show the bad results that follow the *lack* of a certain vitamin or vitamins in the diet.

The experiment just described shows the general procedure followed in studying vitamins. Such an experiment would check on any conclusions previously formed. Experiments like this, when first performed, have to be tried over and over again, with varied amounts and kinds of foods in many different combinations. Checks and rechecks must be made to ensure the accuracy of the results and conclusions. Only in this way can scientific judgments be reached and the truth be established. Burbank, the horticulturist, sometimes would grow 5000 plants from which to select only two or three. An investigator works toward the goal of establishing truth. How long it will take, no man can foretell. Scientific experimentation calls for knowledge, industry, resourcefulness, honesty, and patience.

**180. What has civilization done to foods?** It is an interesting fact that the savages and wild tribes of the world usually maintain good health, although they are totally ignorant of vitamins. This means that if a person has a diet that is ample, varied, and balanced, the necessary vitamins will be included. However, there is still much ignorance, even among civilized man, about the science of diet. The refinements of modern living have given us polished rice, bleached flour, white macaroni, and many kinds of foods lacking certain

## TABLE OF VITAMINS

| Name | Value to Body | Foods Containing | How Affected by Heat or Light |
|---|---|---|---|
| Vitamin A (Carotene) | Helps vision, especially at night; assists growth; prevents eye infection; essential for glandular health | Milk; butter; eggs; carrots; corn; cod-liver oil; halibut-liver oil; shark-liver oil | Destroyed by high temperatures |
| Vitamin $B_1$ (Thiamine) | Regulates digestion; assists normal functioning of nervous system; prevents beriberi | Yeast; coverings of cereal grains; tomatoes; spinach; milk; red meat; liver | Destroyed by long-continued moist heat; also by soda in cooking |
| Vitamin C (Ascorbic acid) | Aids in growth and in maintenance of sound teeth, gums and capillaries; increases resistance to disease; prevents scurvy | All citrus fruits; peppers; cranberries; tomatoes; cabbage; lettuce | Destroyed by heat and by long exposure |
| Vitamin D (Calciferol and Cholesterol) | Necessary for the development of strong bones and teeth; increases resistance to disease | Cod-liver and halibut-liver oils; irradiated oils and irradiated milk; produced in body by sunlight | Not affected by heat |
| Vitamin E (Tocopherol) | Necessary for normal reproduction | Wheat germ; beef; eggs; milk | Not affected by heat |
| Vitamin $B_2$ (G or Riboflavin) | Essential to the nervous system; protects against skin inflammation; aids digestion and growth; prevents pellagra | Yeast; wheat germ; eggs; liver; meat; vegetables; milk | Not affected by heat; affected by light |
| Vitamin P (Eriodictin) | Strengthens the walls of the capillaries | Lemon juice | Destroyed by heat |
| Vitamin K | Aids in the clotting of blood; specific for jaundice | Liver; hemp seed; green cereal seeds; alfalfa | Destroyed by heat and by light |
| Vitamin P–P (Nicotinic acid or niacin) | Prevents and cures pellagra | Yeast; wheat germ; egg yolk | Not affected by heat |
| Pantothenic acid | Aids nutrition and retards the graying of hair | Yeast; whole cereals; liver | Effect not determined |

original substances. We usually pare our potatoes and our fruits, and throw away the skins. In most cases important vitamins are lost when the skins, coverings, or other parts nature had originally given to the seeds or plant are discarded. Now we are trying to bring back our denatured foods to the original condition by adding vitamins. Milk is irradiated by ultraviolet light to produce vitamin D. Vitamins are added to bread and to other foods. We are also learning to cook so as to retain the natural vitamins. It is better to get vitamins by eating balanced meals than by taking costly vitamin pills.

## *Questions*

1. Do you know why English sailors were called " limeys "?
2. Is the scientific method shown in vitamin experiments?
3. What is polished rice?
4. What kind of rice does your family use?
5. What are the symptoms of scurvy?
6. What is the cause and cure of rickets?
7. What vitamin is associated with sunlight?
8. What vitamins does yeast contain?
9. What vitamins do you get by drinking milk?
10. What physical defects follow a lack of vitamin B in the diet?
11. How can beriberi be cured?
12. Lack of enough vitamin C causes what condition?
13. Can you name two vitamins valuable in maintaining the health of the nervous system?
14. What vitamins are destroyed by heat? Not affected by heat?

## *Some things for you to do*

1. Read until you can write an account of the story of vitamins.
2. Visit an institution conducting vitamin experiments. Report.
3. Find out to what extent your family buys whole-wheat foods instead of white flour. What vitamins do you get daily?

# *We Know How to Build Better Homes*

PROBABLY you have watched a pair of robins building a nest. They seem to be happy in such work, and content to follow the same architectural plan that all their ancestors followed. It seems to be an instinct in birds and other animals to build a nest or a home of some kind. We may not all have the pleasure, and also the worry, of building a house and a home for ourselves, but civilized man will probably continue to live in a house, whether he builds it himself or lives in a house built by someone else. Unlike the birds, man, when he finds ways of improving his home, will change manner and plan of construction.

This unit deals largely with what we may call consumer science information which should help the buyer to spend his money intelligently and economically. In the building of a house, for example, there are many things to be considered. We shall want to know whether the material of which we build is strong enough to withstand heavy winds

and rains. We shall want to have the roof and walls insulated against what heat and cold there will be where we build. Since most persons are not likely to build many houses in a lifetime, durability is an important factor. The United States Department of Internal Revenue, in figuring depreciation, assumes that a frame house will need to be replaced after 33 years. Of course houses can be made more durable.

We shall want to make our home livable too. A beautiful home need not cost any more than an ugly one. We can plan our home to make it convenient. Electrical devices of many kinds can be installed to save labor.

## *Think about these!*

1. In what kind of house would you like to live?
2. Would you select your house for its beauty or its durability?
3. If you were building a house, of what material would you build the walls? What kind of roof would you use?

## *Words for this chapter*

**Footings.** Broad foundations upon which the walls of a house are built.

**Toenailed.** Nailed diagonally through the edge of one timber.

**Furring.** Wooden strips to which lath or other material is fastened.

**Veneer.** A surface coating of some material that is more durable or more beautiful than the material that it covers.

**Stucco.** A concrete mixture.

**Creosote.** A chemical obtained from coal tar. It preserves wood.

**Flashing.** Strips of metal used to make watertight joints between a wall and a roof surface or between two intersecting roof surfaces.

**Conduits.** Pipes used to conduct liquids.

**Incinerator.** A device used to burn garbage or other waste.

CHAPTER 8 ——— UNIT 4

# How Should We Plan and Build Our House?

**181. Is the home a mark of civilization?** When our early ancestors lived in caves, there was little or no scientific knowledge used in making the home. It was a refuge and a shelter. The cave man had a few weapons for offense and for defense. He had no art except some crude sculptures and drawings, and he left no literature. The Eskimo of the frozen northland does a little better since he uses the principle of heat insulation in building his igloo. The walls of snow and ice tend to keep the heat from escaping to the outside. The American Indian shows some skill but no science, as he builds his tepee or his wigwam. [See Fig. 8–1.] Some of the grass huts built by natives of tropical regions are not much more elaborate than some carefully woven birds' nests. [See Fig. 8–2.] In marked contrast with such simple dwellings, the modern house which is now built in the middle latitudes, is an application of dozens of scientific principles.

Not every one of you will have the pleasure of building a house of your own, but you are now living, and will con-

FIG. 8–1. How well-ventilated do you think such tents are? Such a home undoubtedly grows very chilly in the depths of winter. (*Courtesy U. S. Indian Service*)

tinue to live, in some kind of house. Whether at some future time you buy a ready-built house, or rent a house, you should know something about the materials used in constructing a house, and whether it was scientifically built. In this chapter on the home, we shall see how the builder uses some of the materials from the earth's storehouses, and how he puts them together to secure *strength, attractiveness, comfort,* and *durability,* at a cost that is not excessive.

**182. Why are footings necessary?** A girl wearing spike-heeled shoes sinks into soft ground farther than does a man who wears broad-heeled shoes, although the man may be considerably heavier. The reproducer of a phonograph weighs only a few ounces, but it exerts a pressure upon the point of the needle equal to many tons per square inch.

Since the foundation walls of a house must sustain nearly all the weight of the entire house, it is necessary to have *broad, flat footings* upon which the walls may rest. The cellar walls may be only from eight to twelve inches thick, but the foot-

ings upon which they rest should be twice that thick in order to prevent their being pushed down into the ground by the weight of the parts above. If the footings are properly built, the house will not settle very far.

Of course the cellar must be excavated before the footings are placed, and the excavations must be deep enough so that the ground beneath them *never freezes.* We have learned that water expands when it changes to ice, and any water in the soil below the footings would cause their upheaval upon freezing. The force of such expansion of water upon freezing is tremendous. In the latitude of New York City, frost seldom or never goes deeper than two and one half feet, even in the coldest winter weather. Farther north, the frost line is correspondingly deeper. Even for porches, footings for the foundation must be at least 30 inches deep in the vicinity of New York.

**183. Of what are cellar walls built?** Many of the substances used to build the walls of houses are taken from the

Fig. 8–2. This house in Tahiti does not seem palatial. There is no chimney, and if there were a cellar, there would be no need for a furnace. (*Pan Pacific Press Photo*)

earth's crust, or manufactured from the earth's raw materials. Since the walls need to be at least eight inches thick, the choice of material will depend upon the expense and upon the locality. The following are in common use.

*a*) *Natural rock.* In localities where limestone, traprock, or field stone is abundant, any one of them may be used in building the foundation walls. They are durable and inexpensive. Sometimes they may be had merely for the labor of collecting them. Walls made of any of the above-mentioned materials should be laid in cement mortar. Then they should be coated on the outside with a layer of cement which has some waterproofing material in it.

*b*) *Brick.* A foundation made of brick is rather expensive, but it is sometimes used, either alone or with hollow tile. If bricks are used, they should be laid in cement mortar and waterproofed from the outside. It is rather strange, but both brick and stone are porous, and water works its way through the pores. Even if the walls are three feet thick, dampness finds its way through, unless the walls are dampproofed or waterproofed.

*c*) *Mass concrete.* For large buildings, and less often for small ones, mass concrete is used for the foundation walls. Forms are built of rough boards. Cement, sand, gravel or crushed stone, and water are thoroughly mixed to make the concrete, which is then poured into the forms and permitted to solidify. [See Fig. 8–3.] Although the mass of concrete may appear to be hard and strong after a day or two, yet it needs at least two weeks to become hard enough and strong enough to build the walls of the house upon it. Then the board forms may be removed.

In mixing the concrete, some contractors take advantage of the person building the house, by using too little cement. Of course cement costs more than either sand or crushed rock. A good mixture should contain one part of cement, two and one half parts of sand, and five parts of crushed stone or of gravel.

Fig. 8–3. One sees such concrete mixers everywhere. Concrete may be used for cellar walls, cellar floors, or for the walls of the building itself. (*Courtesy Portland Cement*)

*d*) *Concrete blocks.* Because mass concrete needs to have a form built of rough boards, it is more expensive to use than are concrete blocks. The concrete blocks are made by pouring concrete into molds and letting it solidify and harden in the molds. They, too, should be laid in cement mortar, and covered with a layer of waterproofed, cement mortar. In many houses, the outside walls are covered with pitch or asphalt.

**184. How shall the cellar floor be constructed?** Naturally the cellar floor must be below the frost line, and it should be several inches in thickness. The bottom layer may be made of ordinary concrete, but such concrete should be covered with a finishing layer about two inches thick. This finishing layer may be made by mixing one part of cement with two parts of sand. If the cellar floor is to be painted, it should first be brushed with a nearly saturated solution of zinc sulfate, and then painted with a special paint intended for concrete.

**185. How shall we secure a dry cellar?** A wet cellar, or one with damp walls, is unpleasant. Furthermore, it is unsani-

tary. The cellar floor is usually lower than the level of the water line in the soil around the cellar. Following a long rainy spell, the water table may be several feet higher than the cellar floor. The greater the difference between the two levels, the greater the pressure of the water becomes. Under such water pressure, the water may seep through the pores of the foundation walls, or it may even be pushed upward through the cellar floor itself. What are some precautions that a builder can take to secure a dry cellar?

*a*) The house may be set upon a hill, where the water naturally drains away from the house. The lawn, too, may be so graded that it will help to carry the rain water away from the house.

*b*) A tile drain around the entire outside wall of the house may be laid at the bottom of the walls to carry away excess water. It must be lower than the top of the cellar floor. Such a drain lowers the water level and helps to prevent excessive

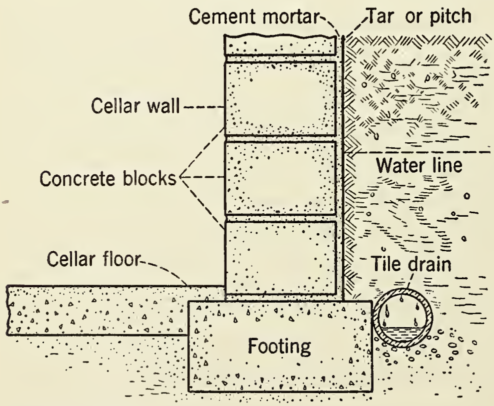



FIG. 8–4. It is very important for a house to have a dry cellar. The walls and floor should be watertight, and a tile drain may be used to carry away excess water.

pressure from soil water. A drain of this kind is a necessity in many locations, and it adds little to the original cost of the house. [See Fig. 8–4.]

*c*) Certain chemicals may be added to cement mortar to make it waterproof. The entire outside surface of the cellar walls should be covered with a rich cement mortar. After the

cement mortar has hardened, a coating of hot tar or pitch should be applied. It is effective, and it costs only a trifle more.

**186. Of what material shall we build the side walls?** The answer to this question may depend upon the purse of the owner, it may be a matter of taste, it may vary with the locality, or it may depend upon the regulations of the building code. In this section we shall briefly discuss some of the materials that are in common use.

*a*) *The frame house.* This type of house is common in the country and in small towns. It is popular because it is less expensive than some other types of houses. Wooden sills are laid, partially embedded in mortar, on the top of the foundation walls. The vertical pieces, which are called *studs*, are *toenailed* to the sills. The studs, which are generally sawed from fir or hemlock, are usually 2 inches wide by 4 inches thick. If a strong frame is to be built, the studs should not be placed farther apart than 16 inches, from the center of one to the center of the next. For the corner posts, two or three

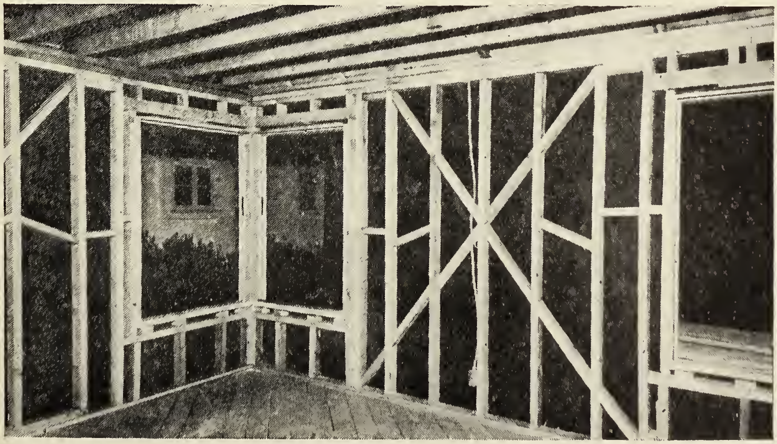


FIG. 8–5. Note how timber is used to make the frame of a house. When studding is cut to make an opening for a window or a door, double-framing is used around the opening. (*Courtesy West Coast Lumberman's Association*)

studs are spiked together. A portion of one or more studs must be cut away to make an opening for doors and windows. In such a case two pieces of 2- by 4-inch lumber are spiked together to make a double frame entirely around the opening.

Figure 8–5 shows how the walls of a frame house are built. To the outside edges of the studs, boards about one inch in thickness are nailed firmly. Such boards are called *sheathing*, or in some localities they are known as *sheeting*. It is claimed

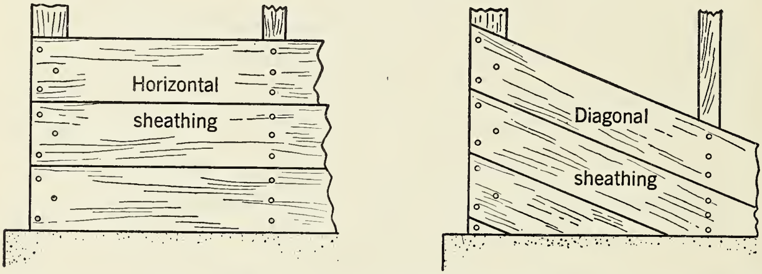



Fig. 8–6. Diagonally placed sheathing is supposed to be stronger than horizontally nailed sheathing.

that the frame of the house will be stronger and stiffer if the sheathing is nailed on diagonally, as shown in Figure 8–6, instead of being nailed horizontally as shown in the same figure. Sheathing is generally made of pine, so sawed that a tongue of wood on the edge of one board will fit into a groove of the adjacent board. *Shiplap* joints are often used. [See Fig. 8–7.]

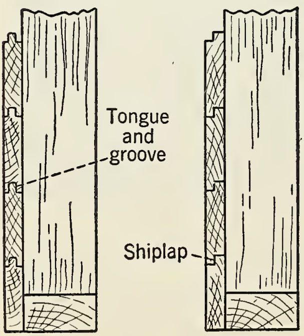



Fig. 8–7. Two methods are used to prevent the wind from blowing through the cracks between adjacent boards. Either tongue and groove or shiplap boards accomplish such a result.

In either case, when the boards shrink, the joint is still tight enough so that the wind does not blow through it easily. To make the construction still more windproof, the whole outside surface of the sheathing is covered with a layer of heavy tar paper, or building paper.

After the tar paper has been tacked to the sheathing, the entire wall may be covered with shingles or with *lap siding* — boards which overlap. As a protection against the effects of the weather and as a preventive for decay, three coats of paint should be applied to the surface of the shingles or the siding.

To the inside of the studding, either wooden or metal laths are nailed. Plaster, which is made by mixing slaked lime and sand, or slaked lime, cement, and sand, is then applied to the lath. If the laths are of wood, they are placed far enough apart so that some of the plaster can be squeezed through the crack between them. Some of the plaster curls down behind the lath. Holes in metal laths are for the same purpose. For that reason the plaster clings rather firmly to the lath. The method of framing described in this section makes a wall about six inches in thickness.

When a frame house is properly built, it is moderately warm in winter, and fairly cool in summer. It needs, however, to have some insulating material placed in the air spaces of the walls, between the studs, in order to help keep the heat from escaping through the walls in winter, and to help prevent the heat from entering the house in summer. Several kinds of insulation materials are in use. They include *rock wool,* which is spun or blown into fibers from molten rock; *zonolite,* a light, fluffy mica; and *alfol,* which consists of very thin sheets of aluminum foil. [See Fig. 8–8.]

The frame house lends itself easily to artistic designs. Its appearance can be changed occasionally, too, by applying paint of a different color.

*b*) *The brick house.* Did you ever wonder how it happens that all the persons you know are so much alike, and at the same time so different that you can recognize each one easily?

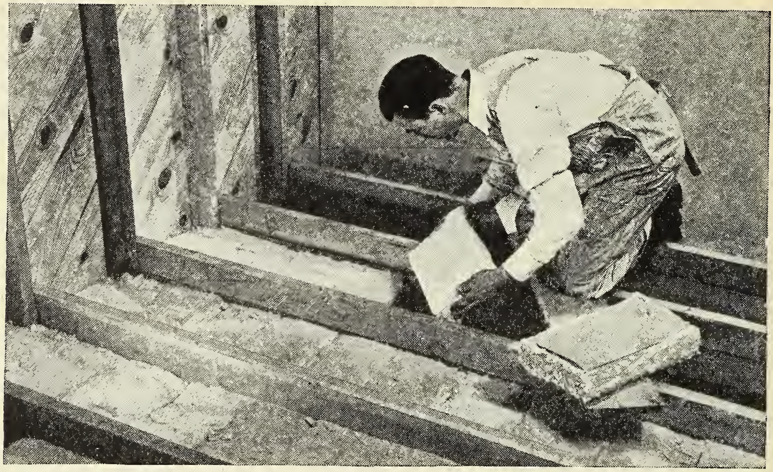


FIG. 8–8. Insulating a house may save as much as 20% of fuel bills. (*Johns-Manville Photo*)

Did you ever wonder, too, how an architect can plan so many different looking houses out of the same kind of brick? *Common* bricks are usually uniform in color. It is possible, too, to use *face* bricks for the walls of a house. They may vary considerably in color and appearance. Face bricks are harder than common bricks, and they vary more in texture. Brick walls are built of brick, laid in either lime mortar or cement mortar. They vary in thickness, but they are usually not less than 12 inches thick in order to give the wall greater stability.

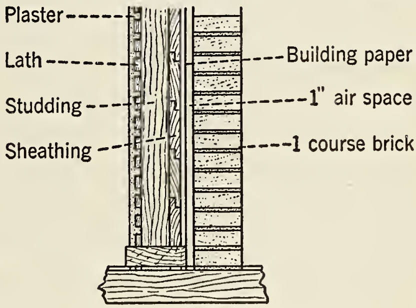
The appearance may be changed by the manner in which the mortar is finished. It may be tooled to a rounded shape or to a V-shape. It may protrude beyond the surface of the brick, or it may be raked from between the bricks to a depth of a half inch or more.

Since dampness readily penetrates bricks, *furring* strips of one-inch material should be placed on the inside wall. To such strips the laths and plaster are attached. This leaves an air space through which moisture does not easily penetrate. It also helps to make the house warm in winter and cool in summer.

The walls of brick houses are practically fireproof, and much of the cost of painting is eliminated. The original cost is generally from 8 per cent to 15 per cent greater than that of a frame house of the same size and design.

*c*) *Brick-veneer walls.* In the brick-*veneer* type of construction, the walls are built just as they are for a frame house, except for the fact that no shingles or lap siding are nailed to the sheathing. Instead of the siding, a single *course,* or layer, of face brick or common brick is used. To secure stability, metal strips are nailed at one end to the sheathing, and at the other end are embedded in the mortar in which the bricks are laid. As a rule, a brick-veneer wall is not carried upward beyond the first story of the house, because a single course of brick does not make a very stable wall for tall buildings. [See Fig. 8–9.]

FIG. 8–9. To make a brick veneer house warm, the brick should be kept far enough from the sheathing to leave a dead air space of at least one inch. Such a house is cooler in summer.




The brick-veneer course should be kept at least one inch from the sheathing to leave an air space to serve as a heat insulator. The use of brick veneer does not add a great deal toward making the house fireproof. It makes a warmer house in winter and a cooler house in summer, and it reduces to some extent the cost of painting.

*d*) *Brick and hollow tile.* For some walls, hollow tiles are used. They are faced with a course of brick. Such walls are strong and they are warm in winter and cool in summer. The lath and plaster must be attached to furring strips, just as in the case of a solid brick wall. Such strips are fastened to the

wall, and the laths are then nailed to the furring strips. With such construction, moisture does not work its way through the walls and cause dampness.

*e*) *Stone walls.* Some of the limestones and certain sandstones make excellent building material for the walls of houses. Field stone and boulders are sometimes used, too. Stone walls are more expensive to build than either frame or brick walls. When stone is used, some dampproofing material must be used, and the plaster should be applied to metal laths nailed to furring strips.

*f*) *Concrete blocks.* Walls made of such blocks are fireproof, durable, and strong, but it is difficult to make them have much beauty. They are not very popular. Thomas A. Edison suggested, a number of years ago, that molds for entire houses could be constructed, set up on a lot, and then poured with concrete. Then of course the molds or forms could be removed and used again. Concrete blocks must be waterproofed, too. The plaster is generally applied to metal laths nailed to furring strips.

*g*) *Stucco walls.* In the building of a *stucco* house, the wall is usually framed in almost the same manner as it is for a frame house. But instead of the shingles or lap siding, metal laths are firmly nailed to the sheathing, and the cement mortar which forms the stucco is then applied to the metal lath. If the mixture of cement and sand is properly proportioned so that it does not crumble or crack, a stucco finish is economical and satisfactory.

Various colors may be added to stucco, and some artistic effects may be produced by the use of a trowel in finishing the surface. Wooden pieces embedded in the stucco can be made attractive. Shells and colored pebbles are sometimes added.

**187. What are the rafters?** A wooden beam, or *plate,* is nailed across the top ends of the studding. One end of the rafter rests upon such a beam, and the other end meets the rafter from the opposite wall of the house to form the ridge of the roof. [See Fig. 8–10.] The rafters are generally made

FIG. 8–10. The strength of this roof depends upon how closely the rafters are placed and upon their length and thickness. (*Courtesy Federal Housing Administration*)

of fir and they should be at least 2 by 5 inches, and long enough to give the roof the proper *pitch,* or slope. A roof that is too flat is more likely to leak than one which has a greater pitch. If a very heavy slate or tile roof is to be used, the rafters may be made of material that is about 2 by 8 inches, and they should be placed not more than 16 inches apart. The boards which are nailed to the rafters should be selected and adapted to the type of roof planned.

If shingles are to be used for the roof, boards 3 or 4 inches wide are nailed to the rafters. The roof is lighter and less expensive if 2-inch horizontal spaces are left between such strips. It is easy to nail the shingles to the wooden strips.

If the roof is to be of slate or tile, tongue and groove boards or shiplap boards are nailed firmly to the rafters and covered with tarred paper, just as the sheathing is placed on the side walls.

**188. What kind of roofing shall we choose?** Every man who builds a house or has one built for him finds questions arising constantly, and he must decide upon the answers. In

the choice of a roofing material, the factors that will affect his choice are original cost, durability, weight, artistic appearance, and flammability. Let us consider some common roofing materials.

*a*) *Wooden shingles.* The small roofing units known as *shingles* are made of different kinds of material. Wooden shingles have been used for years, and they are very common. They are attractive and fairly durable. A good wooden shingle roof may last twenty years. The durability of shingles may be increased by dipping the shingles in *creosote* before they are laid, and then keeping them stained. Wooden shingles may be kept painted, too. One of the greatest objections to wooden shingles is their flammability. In some towns and in most cities their use is forbidden by the building code.

*b*) *Copper shingles.* Small sheets of copper have been used successfully as roofing material. The edges are fastened firmly together to make one continuous piece of metal. A copper roof is watertight and durable. It weathers to form a beautiful green compound of copper. Copper is extensively used for gutters and leaders (pipes to carry off water), and for *flashing* around chimneys and for the valleys between adjoining roofs. Copper expands so much when it is heated and contracts so much upon cooling, that large seams must be used where pieces are attached to one another, or the copper sheets will be pulled loose during changes in temperature.

*c*) *Asphalt shingles.* Felt is sometimes treated with tar or asphalt, for use in making shingles for roofing material. Gravel or bits of slate may be pressed into the asphalt or the tar to make it harder. Such material burns slowly, and it is inexpensive.

*d*) *Asbestos shingles.* Shingles may be made from a mixture of asbestos fibers and cement. Such shingles lie flat and are durable. They are not very heavy, and they are fireproof. They can be obtained in almost any desired color. These shingles cost more than some other roofing materials. [See Fig. 8–11.]

Fig. 8–11. This man is roofing a house with asbestos shingles. Such shingles do not make a heavy roof, and they have the advantage of being fireproof and proof against decay. A roof made of asbestos shingles should last a lifetime. (*Johns-Manville Photo*)

*e*) *Slate.* This roofing material is made from a natural rock which splits easily into sheets of any desired thickness. The sheets may be trimmed to any desired size, and the pieces are then laid much as a wooden shingle roof is laid. Slate may be obtained in such colors as black, gray, purple, brown, green, and red. The first cost of a slate roof is high, but when finished it is durable and fireproof. Beautiful architectural effects can be obtained by the use of slate.

In some types of Gothic houses, the pieces of slate used in roofing are neither of uniform thickness nor of uniform size. The effect produced depends much upon the skill of the man who lays the roof.

*f*) *Tinned iron.* The so-called tin roofs are made of rather large sheets of tinned iron. They are particularly suitable for flat roofs over porches, or for covering rounded windows in roofs. They can be made watertight by soldering the edges together. Such tinned iron roofs will last indefinitely if they are kept painted with a substance known as *prince's mineral.*

*g*) *Roll roofing.* Inexpensive tar-saturated felt roofing is prepared in rolls about three feet wide. This material can be applied quickly, with the saving of labor costs. The edges must overlap two or three inches, and they must be fastened securely. Sometimes such roofing is made in rather narrow strips, cut to resemble shingles. Roll roofing is really more suitable for use on barns and outbuildings than it is for dwelling houses.

*h*) *Canvas roofing.* For flat roofs on boathouses and porches a heavy canvas or duck is sometimes used. It comes in rolls which are tacked on with copper tacks. Such a roof will last a long time if it is given a couple of coats of paint every two or three years.

*i*) *Spanish tile.* These tiles are made from clay and then fired to make them hard and nonporous. Certain types of brick houses look well if they are roofed with Spanish tile. Such roofing is durable. It is expensive, and it is considerably heavier than a slate roof. Therefore the rafters for such a roof must be made of heavy material.

**189. What are joists?** The planks to which the flooring is nailed are called *joists.* They are usually made of fir or of hemlock, about 2 by 10 inches, and long enough to reach from the plate on one side of the room to the one on the opposite side. The joists are set on edge, about twelve inches apart, to give stiffness. Additional strength and stiffness may be gained by the use of *bridging*, which consists of two one-inch pieces of wood about three inches wide, nailed diagonally between adjacent joists. The end of one piece is nailed to the lower edge

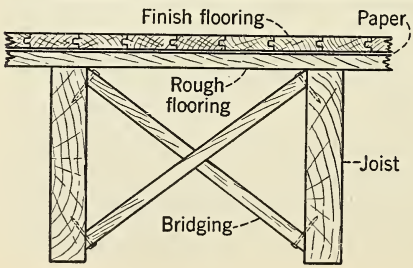



FIG. 8–12. The joists are stronger when set on edge. They must be cross-braced, however, to prevent the floor from vibrating.

of a joist, and the other end is nailed to the upper edge of the joist which is opposite. The second piece is nailed adjacent to the first to make an X-shaped brace. [See Fig. 8–12.]

**190. Floors may be durable and beautiful.** In good houses, double flooring is always used. The *sub-floor* is made of inexpensive tongue and groove boards from four to six inches in width. The sub-floor is then covered with tar paper or building paper before the finish floor is laid. The paper prevents smoke and soot from the furnace or the cellar from working its way up into the house. The plastered walls should be dry and free from dampness before the *finish* floor is laid. That prevents the grinding of particles of sand and mortar into the floor and spoiling it, and it prevents the finish floor from swelling and buckling.

Several kinds of wood are suitable for the finish floor. Either *red oak* or *white oak* makes a beautiful floor. Several grades of oak are available, choice clear, quarter-sawed oak, clear plain-sawed oak, select oak, common No. 1 oak, and common No. 2 oak. When timber is quarter-sawed, the log is first sawed into four quarters. Then each quarter is sawed by ripping off boards alternately from each face. Quarter-sawed lumber is less likely to warp or to check, and the grain of the wood shows to better advantage. Since there is more waste, it is more expensive than plain-sawed lumber. [See Fig. 8–13.]

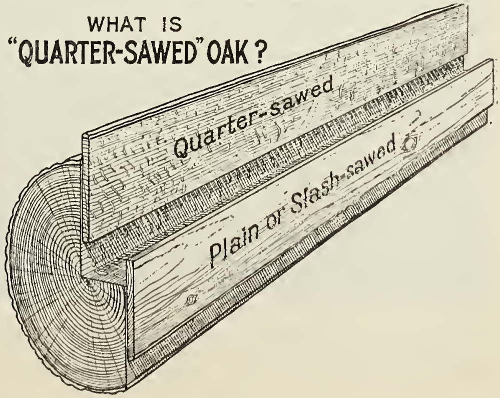



Fig. 8–13. Notice the beautiful grain which shows when a log is quarter-sawed. The grain of plain-sawed oak is not so pleasing. (*U. S. Forest Service Photo*)

The flooring strips are planed on one side and tongued and grooved at the edges and at the ends. When they are pounded together and nailed at the edges, the nail heads do not show on the surface of the floor, and the cracks are very small.

It is not desirable to use oak floors in kitchens, because they become darkened by strong soaps and scouring powders which may be used in scrubbing the floors. As a matter of fact, fumed oak and mission oak are made by treating ordinary oak with ammonia fumes, or with a lye like sodium hydroxide.

The so-called *soft maple* makes excellent flooring. It is used extensively for kitchen floors, since it is white; and it becomes very hard when it is seasoned. Possibly the floor of your schoolroom is made of soft maple. You may find it, too, in the floor of the gymnasium and in the floor of the auditorium. [See Fig. 8–14.]

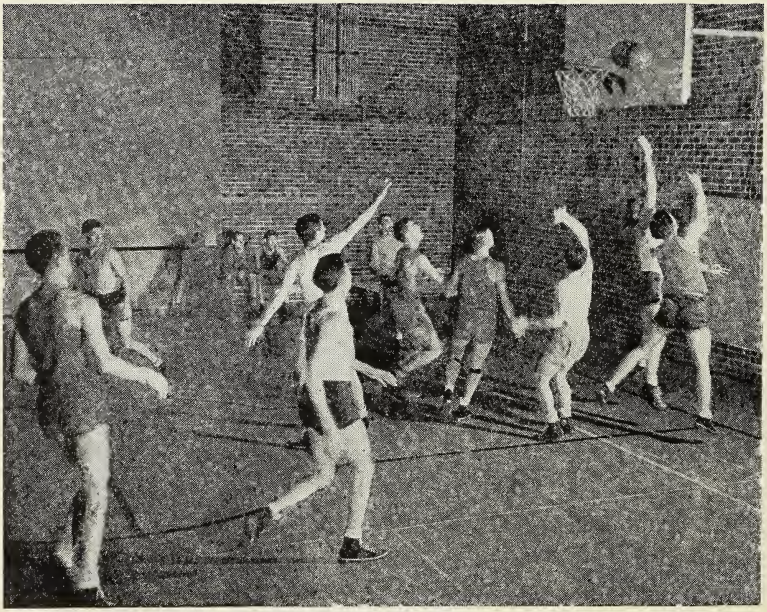


FIG. 8–14. Of what wood is your gymnasium floor made? (*Courtesy Antioch College*)

*Comb-grain pine* is satisfactory for bedroom floors. It is fairly hard and durable. The pine is so sawed that the edge of the grain shows on the top surface of the floor. If sawed the other way, it will crack and splinters will peel off.

**191. How do we depend upon wood?** Even if one builds a brick or a stone house, he will have many uses for wood. The furring strips, the rafters, and the floors are made of wood. The frames of windows and doors are usually made of wood, although they are sometimes made of metal. Since such frames are usually painted, beauty of grain in the wood is not important. Window frames and door frames are often made from the wood of the tulip tree. Such frames must be set vertically, and the casing or trim around them must fit so tightly that wind does not blow through the cracks. White pine is satisfactory for making window sash, and it is often used for outside doors that are exposed to weather conditions. It is very soft, but it does not decay easily. Cypress is sometimes used for making such doors.

Solid, paneled doors of pine or cypress are sometimes used for inside work, especially for second- or third-floor rooms. If hardwood doors are desired, usually some inexpensive, soft wood is used as a foundation by the factory making the doors. Gum is used for such purposes. Then a thin coating of hardwood, such as beech, birch, or mahogany is glued firmly to the foundation wood. This process is called *veneering*.

Wood is also used for trim, such as the casing around window and door frames, molding strips, and baseboards. Sometimes wood is used for paneling. If such trim is to be painted, some soft, white wood, such as that from the tulip tree, is excellent for the purpose, since it does not crack easily. Chestnut, oak, and maple are sometimes used for trim, if the wood is to be varnished or waxed and not painted. Then the grain of the wood shows through the varnish or the wax.

**192. What metals find use in home construction?** In your earlier study of science, you learned that certain metals are found in the earth's treasure house. You also learned how

man takes some of these metals from their ores. Several metals find more or less extensive use in the building of a house. Probably the useful metal, iron, is more widely used than any other metal. When we speak of iron, we include steel, too.

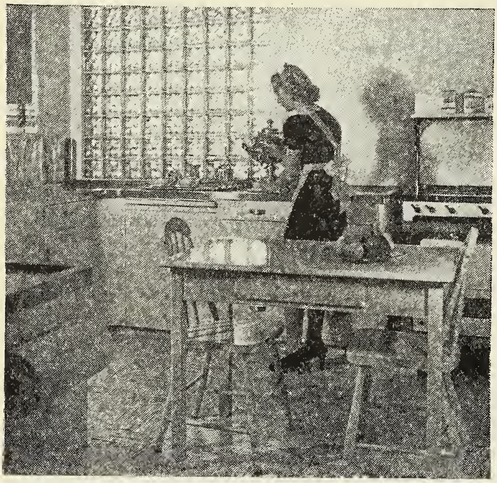


FIG. 8–15. What metals help to produce this orderly, convenient kitchen? Some of the metals you will see in the picture; others are out of sight. (*Courtesy The Pittsburgh Plate Glass Co.*)

*a*) *Iron and steel.* For making metal lath, iron or soft steel is used. The *lally* columns which are used to help support the first floor are usually made of cast iron. Water is brought to our home through pipes made of cast iron or wrought iron. Gas pipe, too, is made of iron, although it is generally *galvanized.* Galvanized iron is made by dipping iron into a vat of molten zinc. The zinc sticks to the outer surface of the iron and prevents rusting. The *conduits* in which electric wires are encased are made of iron. The soil pipes, which serve to carry away wastes, are made of cast iron, as are also the vent pipes for the plumbing system.

No matter what kind of heating system we install, the parts are made largely of iron. This includes the stove or furnace itself, the smoke pipe to connect it with the chimney, the steam pipes and hot-water pipes, and the registers and radi-

ators. Such hardware as weights, hinges, locks, nails, and fasteners are usually made of iron or steel. Window and porch screens, as well as gutters and leaders, may be of galvanized iron. [See Fig. 8–15.]

*b*) *Copper.* We have already referred to the use of copper for roofing, gutters, leaders, and flashings. It is also useful for making insect screens, because it does not rust. Copper is so soft, however, that copper screens are easily torn. Then, too, it tarnishes enough to stain the paint around the screen with a greenish hue. A varnish may be used to prevent such staining, or a thin paint may be applied to the screen.

We shall probably find that the coils in our hot-water heater are made of copper. All our electric wires are made of copper, although we do not see the copper, which is covered with some insulating material.

*c*) *Zinc.* One of the chief uses for zinc around the home is as a protection for iron, to keep it from rusting. Our iron pipes, the smoke pipe, and the insulating jacket of the furnace itself may be made of galvanized iron. Zinc is sometimes used for making metal weather strips which find use in windows and doors to make the joints tighter and prevent the wind from blowing in around cracks.

*d*) *Brass.* This metal is an alloy made of copper and zinc. It is used for the hinges for outside doors and for other hardware. Brass is also used for making water pipes, both for the hot-water and the cold-water pipes. It costs more than galvanized iron pipes do, but it does not rust through and result in leaks with the attendant plumber's bills.

*e*) *Lead.* This soft, bluish-white metal finds some use in making drain pipes which lead from sinks and other drains. It corrodes at the surface only, and it is very durable. Because lead is soft, a lead pipe may be bent into almost any desired shape. No water which has stood in contact with lead pipes should ever be used for drinking purposes, because water containing carbon dioxide in solution will attack lead slowly, forming slightly soluble compounds which are very

poisonous. Solder is an alloy made from lead and tin. In our study of paints, we shall learn that the bulk of most paints is made from compounds of zinc and lead.

*f*) *Nickel and chromium.* The faucets and pipes used for the bathroom, the lavatory, and the kitchen fixtures are usually made of iron or brass. To prevent corrosion, they are then plated with nickel. At the present time, plating with chromium is more common, since a chromium-plated metal needs little or no polishing. Hinges for bathroom doors should be either nickel-plated or chromium-plated.

*g*) *Enameled iron.* In modern bathrooms and lavatories, the wash basins, the bath tubs, and the toilets may be made of porcelain. Many of them are made of enameled ware. To produce the enamel glaze, a mixture of powdered chemicals much like those used for making glass, is applied to the surface of the iron, and baked until the mixture just begins to melt. The glassy surface or glaze thus formed protects the iron from rust and corrosion. Kitchen sinks made from enameled iron are durable, but their surfaces may be roughened by the action of acids or strong alkalis. Even lemon juice attacks the glazed surface of enameled iron sinks. Since enamel is glasslike, it will crack if struck by a hammer or some other hard instrument.

**193. Why is the plumbing system so important?** Probably no one thing affords a home owner more satisfaction than a well-planned, properly installed plumbing system. In our earlier study we learned how city dwellers have at their disposal water under pressure which can be used to flush wastes into the sewers. Soil pipes about four inches in diameter lead through the cellar floor to the sewers buried below the streets. It is the duty of the building inspector to see that all sinks and toilets have traps to prevent sewer gas from entering the house. A vent pipe must extend upward through the roof. This will let in air and prevent the water from being siphoned out of the traps under the sinks, toilets, bath tubs, and floor drains.

*194. **How shall we dispose of garbage?** One living in the country may use the waste scraps of foodstuffs in the garbage as food for pigs. He may bury it underground, use it as a fertilizer, or he may burn it in a small *incinerator*.

In most cities, garbage is placed in metal cans, and collected at regular intervals by men employed in the scavenger service. Sometimes it is carried far out into the ocean on scows and dumped into the sea. This may be unsatisfactory if it is washed ashore to pollute bathing beaches. Some cities have out-of-the-way places for dumping garbage, and still other communities use incinerators to dispose of garbage wastes.

*195. **How shall we dispose of waste papers?** Old newspapers, old magazines, and waste paper from the wrappings for packages are constantly accumulating around the home. They may become a fire hazard. In many localities, waste paper is collected and sold for use in making print paper. This is good conservation.

196. **When are waste products not wastes?** It is hardly fair to speak of something as a waste if it can be put to some practical use. It has been said that some European families could live on the foods which the average American family throws into its garbage pail. That may or may not be true, but it is certainly true that many valuable things do find their way into what is known as "wastes." Let us consider a scientific method of handling garbage.

In a well-governed city the garbage is collected and taken to a garbage-disposal plant. It is there treated with gasoline to dissolve the fats which are present in the garbage from suet and other forms of grease. The gasoline is recovered to be used over and over again. The fat which is recovered goes to the soap manufacturer. He treats the fat with lye and converts it into soap. The portions which do not dissolve in the gasoline contain many compounds that are valuable as plant fertilizers. They are sterilized and sold under the name of *tankage* to the manufacturers of commercial fertilizers.

The city of Columbus, Ohio, has a sewage-disposal plant

which makes it possible to use sewage wastes for fertilizer. The sewage is aerated to destroy dangerous bacteria.

Magazines and periodicals accumulate in the home. They are much sought by shut-ins in various homes and hospitals. The Salvation Army workers are glad to collect and distribute them to places where they will be used. You have seen the enormous catalogues which are distributed free of charge by some mail-order companies. The story is told that one mail-order house had been receiving a large number of orders for catalogues from a nation in Asia. When no orders for merchandise were received, an investigation showed that the catalogues were being used by a paper manufacturer in that country as material for making print paper.

## *Questions*

1. What do you understand by the term *footings?* What precautions must be taken in laying footings?

2. If you were building a home, what precautions would you take to ensure having a dry cellar?

3. What safeguards should the builder of a frame house use to prevent destructive fires?

4. Suppose you are an architect. What advice would you give a person who is planning to build a home, concerning the building of a frame house? A brick house? A brick-veneer house?

5. In building a brick-veneer house, why should the brick course be kept about one inch from the sheathing? Why is it not desirable to carry the brick-veneer course above the first story?

6. Why are houses built with hollow walls?

7. What is the advantage in filling the hollow walls of a house with insulating material?

8. Galvanized iron strips or strips of zinc are sometimes inserted in grooves along the edges of window sash. What is the purpose in using such weather strips?

9. If you were building a house for yourself, what type of wall construction would you use? Be prepared to give a two- or three-

minute talk to explain to the rest of the class why you made the choice you did.

10. Try to imagine that you are a salesman for slate roofing. Prepare a three-minute talk intended to convince your classmates that they should use slate roofing when they build a home.

11. Talk to an architect, a builder, or a contractor who lives near you. Ask him about the relative merits of different kinds of roofing materials. Come to class prepared to discuss the choice of materials with your classmates.

12. Make a list of some of the woods used by builders and tell for what purpose each one is valuable.

13. What do the following terms which are used by builders mean to you: *joists; studs,* or *studding; plates; sills; shiplap; tongue and groove; bridging; sheathing; rafters; lap siding?*

14. Gold has been called the king of metals. Give arguments to show why iron has a better right to such a title.

15. How many ways can you think of that are used to prevent the rusting of iron?

16. What is galvanized iron? What is ordinary tinware?

17. What is meant by the term *alloy?* Mention two alloys. Give the composition and the uses of each one.

18. What is the purpose of a trap in a sink or toilet?

19. What prevents a trap in a sink or toilet from acting as a siphon?

20. How does your town or city collect garbage? How does the city dispose of it?

## *Some things for you to do*

1. Make a small section of a wall such as might be used in a frame house.

2. Collect samples of the different kinds of roofing materials.

3. Make a collection of samples of as many insulating materials as you can find in your locality.

4. If a new house is being built in your neighborhood, you may be able to get small pieces of waste wood. If so, take them to class and try to identify them. Be prepared to state for what part of the house each one is being used.

## THINK ABOUT THESE!

1. Four bare walls may make a prison. What can be added to such walls to make a home?

2. Can you give any reasons why you prefer papered walls or why you prefer painted walls?

3. Have you ever given any thought as to how your home can be made more livable?

## WORDS FOR THIS CHAPTER

**Ornate.** Elaborate; highly decorated.

**Mullioned.** Having divisions formed by slender bars or pillars.

**Three-way switch.** A switch so wired with a second switch that either switch may operate the same light.

**Taupe** (tōp). A dark gray or moleskin color.

**Opaque** (ȯ·pāk′). Not permitting light to shine through.

**Linoxyn** (lĭ·nŏk′sĭn). The name given to the leathery skin formed when oxygen unites with linseed oil.

**Scrim.** A light, coarse, cotton fabric.

**Stippled.** Painted with short strokes of the brush, or having the surfaces of fresh paint roughened by being patted with the ends of the bristles of the brush.

CHAPTER 9 ——————— UNIT 4

# How Can We Make Our Home Beautiful and Livable?

**197. Feeling at home.** Possibly at some time you entered a house where you immediately felt at home. It might have been due to the friendliness of your host and hostess, but possibly that feeling of "at homeness" might have been due to the warm, inviting atmosphere of the rooms themselves. At another time you may have entered a home that was more costly and more luxurious, and found that the feeling of cheerfulness and restfulness of the more humble home was entirely lacking. Possibly the more pretentious house was poorly planned; maybe it was poorly lighted; maybe the draperies were not in harmony with the other parts of the room and its furnishings; or possibly the entire color scheme may have been lacking in harmony.

When the time comes for you to build and furnish a home of your own, you will do well to "live" with your plans for a few months before the building is begun. Study where your electric outlets should be placed for convenience. Imagine your furniture in place in the new rooms. Does it fit into the

wall spaces? Is there room for the doors to swing without striking against something? Do you think the window space will be large enough to give sufficient light? It is easy and inexpensive to change plans on paper.

**198. What type of house shall we build?** There has been much improvement in architecture since the days when the early settlers cut down the trees, hewed them on two opposite sides, and piled up the logs to make a box-shaped log cabin. Of several types of houses that are common, the one chosen should conform to the size, shape, and elevation of the lot upon which it is to be built. The styles vary from the square, roomy house with a rather flat roof to the extremely *ornate* houses that may combine several types of architecture.

The American Colonial type of house, which is common in New England, has a center hall which usually has a door both front and back, thus giving a view through the hall to the rear lawn and the gardens beyond. It has always been popular.

In some localities the Dutch Colonial house is common, and in others the English type of house is much used. In various parts of the United States, we find houses that show the influence of the Spanish, French, Georgian, or Italian styles of architecture. [See Fig. 9–1.]

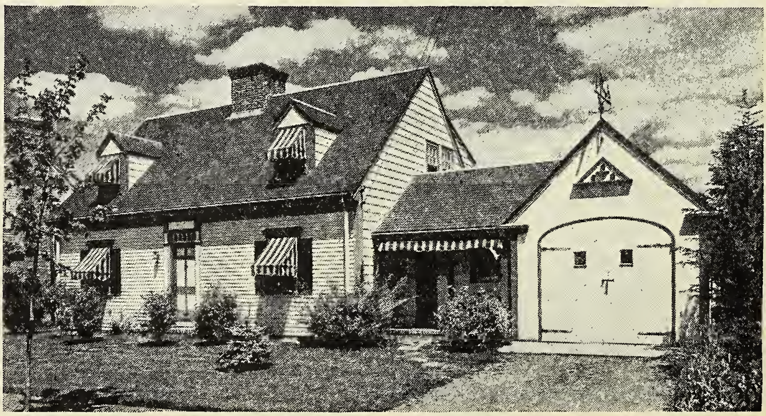
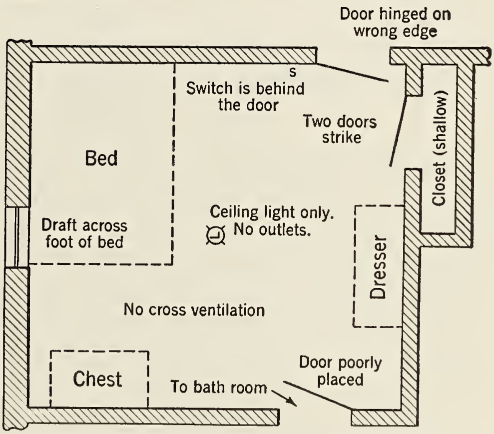


FIG. 9–1. How would you describe this modern house? Does it look livable? (*Courtesy Sherwin-Williams — F. S. Lincoln Photo*)

**199. How shall we make the floor plans?** Have you ever tried to draw some floor plans for a house in which you would like to live? It is both interesting and instructive. You will find it easier if you take a good-sized sheet of cross-section paper and let each small space represent one foot, or two feet, depending on the size of the paper and of the house. Before you begin, you should take care to avoid waste space, such as a long, narrow hall. The plans should provide, too, for easy passage between the most-used rooms in order to avoid extra steps for the occupants. Door and window openings should be so planned that there is plenty of wall space between them for the furniture. Too often one sees a bedroom so poorly arranged that it is nearly impossible to find a place for the bed. [See Fig. 9–2.]

FIG. 9–2. Several things about this bedroom show that it was poorly planned. Make a list of as many of them as you can.




All rooms should have plenty of window space. The plans should provide, if possible, for cross ventilation, especially in bedrooms or sleeping rooms. Adjoining doors should be so hinged that they do not overlap one another when opened. A pair of pencil compasses, with the point of one arm placed at the hinged side of the door, and the pencil arm at the opposite edge, may be swung to describe an arc. The arc described will show how much space the door will occupy when open or when being opened. It is just as easy to place the electric

switches and outlets in convenient places as it is to hide them behind doors. You will find floor plans of houses given in some newspapers, and in home magazines.

200. **A floor plan for your critical study.** Let us study the floor plan of Figure 9–3 to see how well it includes some of the

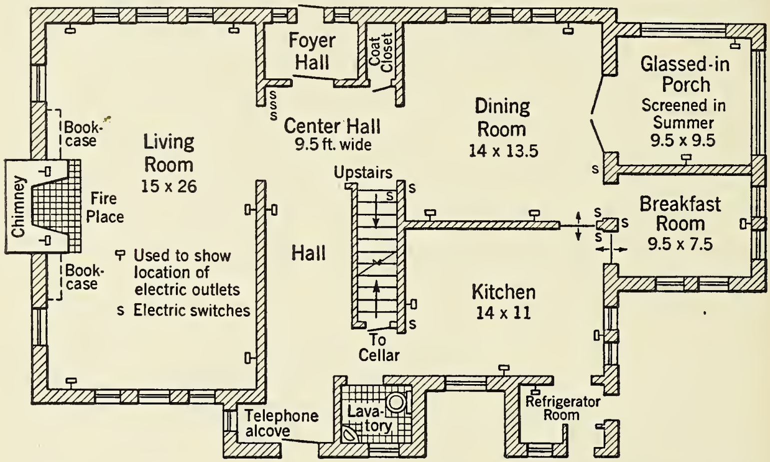



FIG. 9–3. This diagram shows the floor plans of a fairly large colonial type of dwelling. Do you think that it is well-planned?

suggestions for comfort and convenience that are outlined in the preceding section. All plans must be drawn to scale. For a dwelling-house plan, an architect usually uses a scale of one-quarter of an inch to represent one foot. In this plan, you will observe the following parts.

*a*) *The foyer hall,* or its equivalent, with its wide, inviting glass doors saves fuel in winter, since the inner door can be kept closed while the outer door is open. Its floor is tiled. Hence it offers a good place for removing rubbers and galoshes, or for leaving umbrellas.

*b*) *The center hallway* is broad enough to allow room for an ample stairway leading to the second floor, and plenty of ventilation when the door at the rear is open in summer. A coat closet opens from this hall. The broad center hall gives an impression of spaciousness without much waste space.

c) *The living room,* at the right as you enter, is well-proportioned, and has plenty of wall space for the furniture. The fireplace with a large mirror or a picture above it makes an excellent focal point to attract attention as one enters the room. Bookcases are built in on both sides of the chimney. The *mullioned* windows at the ends of the room, with the two windows on the side are adequate for light and for ventilation.

d) *The dining room* is accessible from the center hall, the kitchen, or the breakfast room. With its double doors of glass leading to a glassed-in porch, it becomes a cheerful room, and cheerfulness at meal times is believed to be a good sauce for digestion. The windows of the glassed-in porch can be replaced by screens in summer. This porch has a tiled floor and stuccoed walls which are not injured by the rain blowing in during the summer. This porch in winter affords a good place for a box of plants or some potted plants, or it makes an excellent location for an aquarium.

e) *The breakfast room* is large enough to accommodate six persons. It is so arranged that guests can enter it without passing through the kitchen, and it can be shut off entirely from the kitchen. The floor is covered with inlaid linoleum.

f) *The small lavatory* on the first floor, with a telephone alcove just opposite it, is a great convenience, and it protects the bathrooms on the floors above from unnecessary wear and tear.

g) *All electric switches* are placed just three feet from the floor, and the members of the family have no trouble finding them in the dark. A *three-way switch* controls the dining-room lights as one enters from the hall or when he enters from the kitchen. Another three-way switch controls the kitchen lights as one enters from the dining room or from the hall. A third three-way switch controls the hall light from the front hall or from the upstairs hall. Such switches save many steps for the occupants of the home. Convenient electrical outlets cost comparatively little if installed when the house is

being built. Twin outlets cost no more than single outlets. In our plans there are five in the living room, in addition to one in the floor and one at each end of the mantel over the fireplace. There is one in the hall and one in the breakfast room, just a trifle higher than the table. There are three in the dining room and two in the walls of the glassed-in porch.

*h*) The modern kitchen may best be discussed if we refer to the larger scale plan of the kitchen which is shown in Figure 9–4.

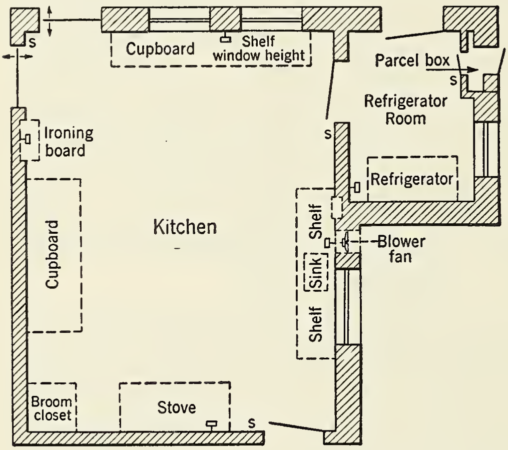



FIG. 9–4. Every kitchen should be planned so that the person who has to work in it does not grow tired from walking.

**201. How can we have a convenient kitchen?** Since the kitchen floor must be washed frequently, we shall cover it with inlaid linoleum. If we can afford the expense, we shall tile the walls of the kitchen to a height of about four feet. In some towns the building code specifies that the floor beneath the gas range must be tiled.

Our gas range is of the modern "fireless" type. We shall place the enameled iron sink with its long shelves on either side directly beneath a large window. If the sink is deep enough for the use of an electric dish washer, we shall want an electric outlet just above the sink. The same outlet will be useful, too, if we have an electric mixer to beat eggs, stir up cakes, or whip cream.

To save space we shall have a small, enameled iron cabinet built in the wall for the soap, brushes, steel wool, and other articles. A built-in, folding ironing board helps, too, to save space. A blower to remove odors from the kitchen may be built in an outside wall or placed in the upper half of an outside window.

This kitchen provides a large amount of cupboard space. The small refrigerator room adjoining the kitchen contains the electric refrigerator. It has shelves for pots and pans, too, and a parcel box built in an outside wall. This box has two doors. The inner one can be kept locked, and the outer one may then be opened by tradesmen when delivering parcels.

**202. How shall sleeping rooms be planned?** In a bungalow type of house all the rooms are on the first floor. In many homes, the sleeping rooms are located on the second floor. In such rooms care must be taken to see that there is wall space for the beds, and that they can be so arranged that the sleeper will not lie in a direct draft. Provision should be made to

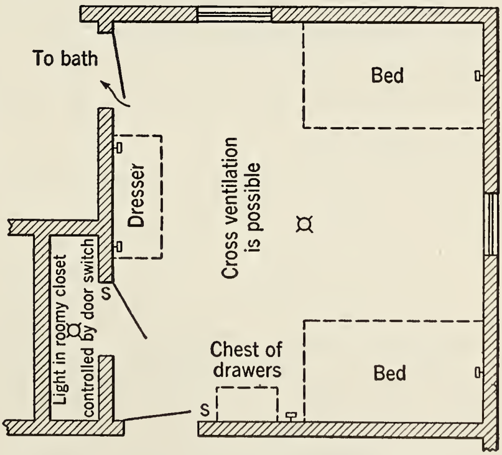



FIG. 9–5. How does this bedroom compare with the one shown in Figure 9–1? Both appear to be of the same size.

secure cross-ventilation, if it is possible. Each bedroom should have ample closet space. [See Fig. 9–5.]

**203. The bathrooms.** The modern bathroom, with its tiled floors and walls, and its chromium-plated plumbing fix-

tures, is a thing of beauty. But tiling is heavy, and if plaster cracks are to be avoided, double-framing should be used all around the bathroom floor. Cinder concrete is often used for the base of the floor upon which the tiles are to be laid. Cinders, however, in contact with a galvanized iron pipe cause the pipe to rust through rather quickly. Too often the water pipes used in bathrooms have had to be replaced within two or three years because cinders used in the concrete were permitted to touch the pipes. Ordinary concrete is a preservative for iron. Pipes in the bathroom may be protected from rusting by having the mason use a cement and sand mortar around the pipes themselves, and then fill the space between the pipes with the cinder concrete.

**204. What shall govern our choice of color?** Almost everyone knows that some colors harmonize when used together, and that other colors clash. For that reason many persons are afraid of color, or they fail to use it effectively. If you live near a large city, and you are uncertain what color combinations to use in decorating your home, you may step into a large department store and get the advice of an interior decorator. Many stores offer such service without charge. If you use your own judgment, you should keep in mind certain suggestions.

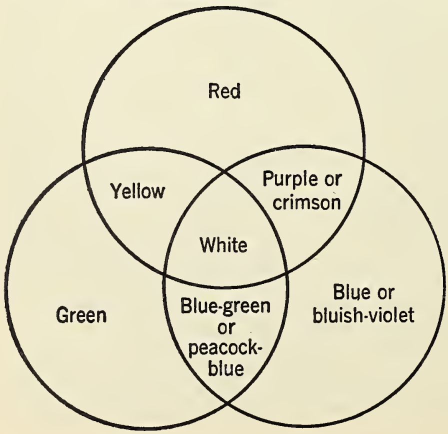



FIG. 9–6. Red, green, and bluish-violet are primary colors. When lights from these three colors are blended, they produce white light. We see that a proper blending of red and bluish-violet produces purple. Complementary colors of light do not apply to pigments.

*a*) In compound light three colors have been found from which any other color can be obtained, if the three are properly mixed. They are known as the *primary colors*, and it is possible to blend them so that white light can be produced. The three colors are red, green, and bluish-violet. [See Fig. 9–6.]

*Any two colors that blend or unite to produce white light are said to be complementary colors.* Blue and yellow are examples. Other examples of complementary colors are bluish-green and red, or green and purplish-crimson. As a general rule, *complementary colors are also contrasting colors,* since each one strengthens the other.

*b*) A small room must never be papered or painted in dark colors. They not only make the room darker, but they also make it seem smaller than it really is. For example, a small room which has been papered with dark green or dark red colors will appear from 10 per cent to 20 per cent bigger if it is repapered with a light cream or yellow paper.

*c*) Some colors, such as yellow, red, orange, and buff, are known as *warm* colors. On the other hand, blue, green, and violet are *cool* colors. Cool colors are desirable for many rooms. Rooms on the northern side of a house may be more livable if painted or papered in warm colors. Some cool colors may be used to advantage in rooms having a southern exposure. Sunlight adds cheer to a room. Tones of color may be dark or light. Light colors are brighter and more exciting. Darker colors are quieter in their effects.

*d*) The walls and ceilings of a room should be finished in tones which are somewhat lighter than the rugs or the floors. This does not mean that floors should be given a dark finish. The natural grain of the white-oak or the red-oak floor is best preserved by the use of a varnish which is almost transparent. Rugs of *taupe,* or some other solid color, generally make the problem of decorating the home an easier one.

*e*) Touches of bright color lend real beauty to the home. Such colors are garish if used extensively. Bright colors are

most successfully added by the use of small oriental rugs, draperies, table covers, coverings for occasional chairs, lamp shades, and vases.

205. **Of what does a paint consist?** A paint is always composed of two things, and sometimes three or more. We always find in a paint the following: (*a*) a white, *opaque* substance which is called a *paint base;* (*b*) an oil, such as linseed oil, with which the paint base is mixed. Such an oil is called a *vehicle.*

In addition to the two substances just named, always present in a paint, we may find some of the following: (*a*) a *pigment,* which is added to give the desired color to the paint base; (*b*) a *drier,* which is used to make the paint harden more quickly; (*c*) a *thinner,* such as turpentine; (*d*) an *extender,* which is a cheaper substance than the paint base, designed to increase the bulk of the paint, and in some cases to make the paint wear better.

206. **What properties should a good paint base have?** An ideal paint base should have the following properties. (*a*) It should be opaque to light, even when it is brushed out in very thin coats. A small quantity of such a paint base will cover a great deal of surface without permitting the surface underneath to be seen through the paint layer. (*b*) It should mix well with the vehicle, and it should not settle when the paint stands. No doubt you have noticed that many ready-mixed paints need a great deal of stirring before they are ready for use. (*c*) It should be durable and wear well. Some paints peel off easily, and others become so chalky that the surface layer rubs off. (*d*) A paint base should be inactive chemically. Then it will not unite with the linseed oil, with the pigment, or with the substances that are present in the air itself. (*e*) It should work well under the brush so that it can be spread evenly over the surface without too much labor. (*f*) It should be nonpoisonous to the workmen who have to work in the factories where it is made, or to the painters who have to apply it. (*g*) It should be rather inexpensive.

207. What paint bases are in common use? Rather a large number of substances have been used or are being used as paint bases. Some of them have rather a limited use, but a few of them are used extensively. [See Fig. 9–7.]

*a*) *White lead.* This paint base, which has been used for centuries, is made by treating sheet-lead discs, or *buckles*, with acetic acid and carbon dioxide. Acetic acid is the acid that is found in vinegar in very dilute form. The process of making white lead usually takes from six weeks to ninety days.

This paint base meets nearly all the requirements of a good paint base which were mentioned in the preceding section. It does tend to become chalky, however, and it is a poisonous compound. If this paint gets into the painter's blood through

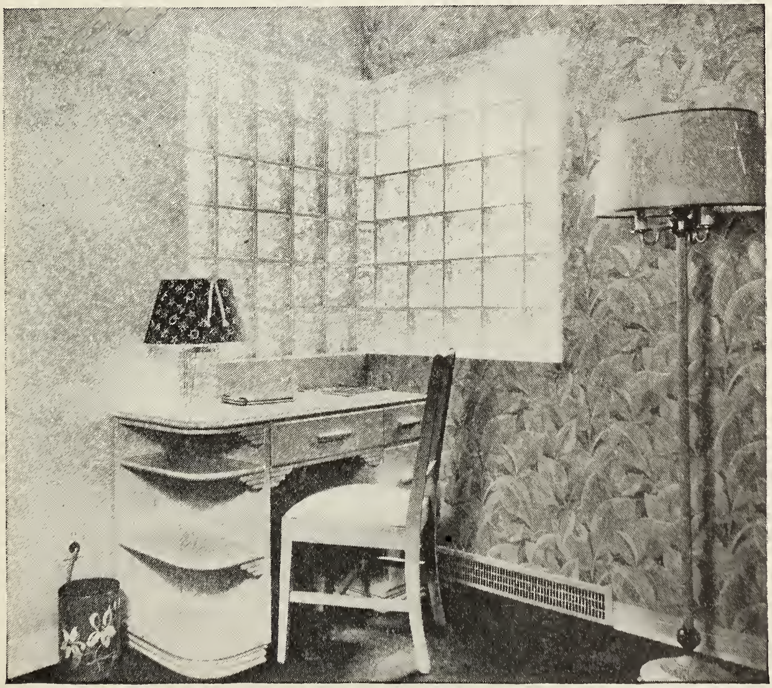


FIG. 9–7. What colors of paint would you choose for this room? Do you think a base was used in painting the desk? If so, what kind may it have been? (*Courtesy The Pittsburgh Plate Glass Co.*)

a crack in his skin, or if he is not careful to wash his hands before eating, he may suffer from what is called painter's colic. He may become unable to control his wrist muscles, and suffer from what is called wrist-drop. The use of white lead as a paint is forbidden in some countries. White lead has a tendency to become dark if it is used as an inside paint, because it is attacked by the fumes of certain compounds of sulfur which escape from fuel gas or from burning coal.

*b*) *Zinc white.* This compound, which is really an oxide of zinc, is made by burning zinc in air, or by roasting one of the ores of zinc. It is whiter than white lead, and considerably less dense. One pound of zinc white will cover more surface than one pound of white lead, but one gallon of white lead will cover more surface than one gallon of zinc white.

Zinc oxide has one bad fault. It tends to crack and peel off. It is an interesting fact that a proper mixture of white lead and of zinc white neither peels off nor becomes chalky. Each paint seems to *nullify* the bad faults of the other. Hence mixtures of the two paint bases are often used.

*c*) *Titanox.* A very white paint base composed of *titanium* (tī·tā′nĭ·ŭm) oxide is called *titanox.* It is whiter than either zinc white or white lead. It is durable, and it does not darken in air or in sunlight. It is inactive, too, and it does not unite easily with pigments. Titanox is usually added to some other paint base.

208. What is the purpose of the vehicle? The oil used as a vehicle in paints must be a *drying oil.* It must do more than merely mix with the paint base so it can be spread easily. The oil must dry, or harden, when exposed to the air; and it must form a *film* which will hold the paint in place. No doubt you have noticed the tough, leathery film which forms on the surface of a partially-used can of paint that has stood for a few days. That film is formed by the linseed oil of the paint taking oxygen from the air and uniting with it to form a new chemical product which is hard and tough. Without a vehicle, any paint base would rub off the surface to which

it is applied, just as chalk rubs off a blackboard. When the oil dries, the film it forms holds the particles of the paint base firmly embedded in it. The drying of a paint is not an example of evaporation, but *of the absorption of oxygen,* either from the air or from some chemical used as a drier.

**209. What vehicles are commonly used?** There are many natural oils, such as olive oil, cocoanut oil, and peanut oil, but only a few oils dry, or take oxygen from the air when exposed. Of course no one would ever think of using a drying oil to oil machinery, but the following drying oils are used in the paint industry.

*a*) *Linseed oil.* The flax plant gives us two important products: the fiber from which linen fabrics are made, and the seed from which linseed oil is obtained by squeezing the seeds in a press. In drying, linseed oil makes a strong, durable film, known as *linoxyn.* Linseed oil is used more extensively in the paint industry than any other vehicle. The so-called boiled linseed oil is made by heating the raw oil. Boiled

FIG. 9–8. A tung-oil plant grown at Gainesville, Georgia. Much of the oil from the tung-oil plant comes from China. It is possible that the Chinese and Japanese monopoly may be broken in the not too distant future. (*Courtesy of Atlantic Coast Line Railroad*)

linseed oil dries faster than the raw oil does, but the film does not seem to last so well.

*b*) *Chinese wood oil.* This oil is made from the *tung* tree, a native of China and Japan. Much of it has been imported from China, but efforts to grow tung trees in Florida, Louisiana, and some other southern states appear to be meeting with success. Tung oil, or Chinese wood oil, is an excellent vehicle for paints, varnishes, and enamels. It forms a harder film than does linseed oil, and its film resists the action of air and moisture better than the linoxyn film. [See Fig. 9–8.]

**210. How are pigments used?** Even if one wishes to have a colored paint, he starts with a white paint base. Such a base is cheaper, and it forms the bulk of all paints. To the white paint are added the pigments needed to produce the desired color. Just as a single drop of red ink will tinge a whole glass of water, so a small quantity of pigment can impart color to a large quantity of paint. Some pigments are obtained from plants and coal tar, but many of them are insoluble mineral products, such as the compounds of iron, lead, zinc, chromium, cobalt, and mercury.

When adding a pigment to a paint base, one must be careful to see that the pigment does not unite with the paint base to give a color entirely different from that desired. For example, ultramarine contains some sulfur. If it is added to white lead, it unites with the white lead to form a black compound instead of the blue color that is desired. It is a good plan to test a small quantity of the paint base with a tiny amount of the pigment before adding the pigment to the bulk of the paint base. The pigments that are listed in this section comprise only a few of those in use. Many of the dyes made from coal-tar products are converted into pigments.

**211. What are thinners?** Such substances as turpentine, alcohol, and mineral oils are not vehicles, but thinners. They dilute the paint and make it flow more freely under the brush. They dry by evaporation, but they do not produce the film that is so necessary in a drying oil. For inside use, they

evaporate quickly, and hasten the hardening of fresh paint. They serve, too, to prevent wrinkling which may occur when linseed oil dries too rapidly.

**212. Why are driers added to paints?** Some paints dry very slowly. That is true for some of the green paints, and it is always true when lampblack is added to the paint base to produce a gray color. It is not pleasant to have wet paint around the house for a long time. We know that paint dries by taking oxygen from the air. To make a paint dry more rapidly than it normally would, we may add some substance which is rich in oxygen. Such a drier gives up some of its oxygen to the linseed oil or other vehicle and makes it harden more rapidly. Some driers are lead and cobalt soaps.

**213. What is varnish?** Both paint and varnish are used to protect surfaces of both wood and metals, since they tend to prevent decay or rust. Paint covers the surface with an *opaque* layer, while varnish is usually *transparent* enough so the grain of wood, for example, can be seen through it.

Several compounds found in nature are known as *resins.* Most of them are formed from the sap of certain trees. When the sap is exposed to the air, the resin is formed. Such resins as *amber, copal, kauri* (kou'rĭ), *rosin,* and *lac* find use in making varnishes. In being converted into varnish, these resins are heated with turpentine, linseed oil, or Chinese wood oil. The cheapest varnish is made from resin and linseed oil. Excellent varnishes are made of copal and tung oil.

**214. How do we obtain shellac?** Lac is an extremely interesting product. An insect, no more than a small fraction of an inch long, punctures the bark of certain trees which are found in India and secretes a resin known as lac. The lac hardens and covers the insect. After the insects swarm, they leave a scale upon the bark. This scale or shell is collected by the natives, warmed, and strained to make the *shellac* of commerce. It is estimated that it takes 150,000 tiny insects to make one pound of shellac. Millions of pounds of shellac are used every year. It is easily made by

dissolving in alcohol, and it dries quickly, as the alcohol evaporates. It is hard and nearly transparent, but brittle.

**215. What are the properties of a good varnish?** In order to be effective, a varnish must form a hard, tough film when it dries. It should not crack or peel off. To test a sample, draw the point of a knife across it; the portion cut away should form a tough thread. A poor, cheap varnish is so brittle that it forms a tiny cloud of dust particles when a pointed object is used to scratch it in that manner. A good varnish does not appear whitish after a damp rag has been left in contact with it for a few hours.

Varnish is sometimes added to a paint to give it a harder finish and a more glossy one. Such products are sometimes called enamels.

**216. What are lacquers?** A number of rather new products are now being used more and more to take the place of paints and varnishes, especially for the finishing of automobiles. Sometimes varnishes are baked on the surfaces which they cover.

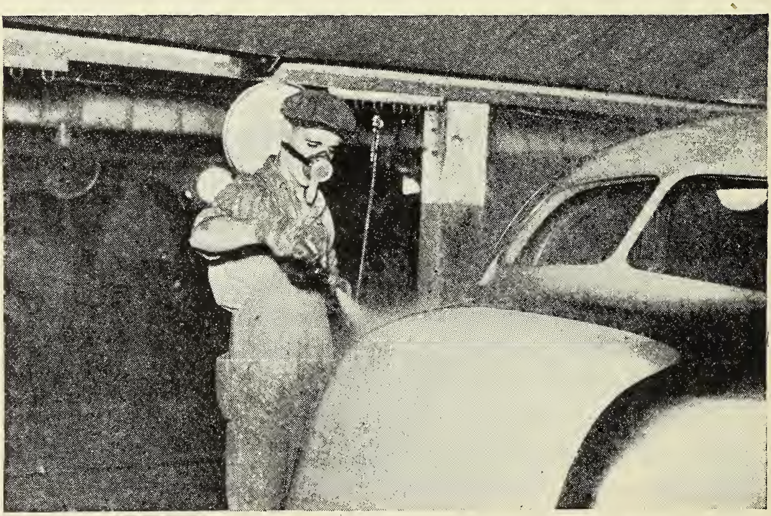


FIG. 9–9. Paint or lacquer is being applied by means of a spray gun. (*Courtesy of General Motors Corp.*)

When these cellulose products are dissolved in an alcohol which has a rather high boiling point, they form *lacquers*. This lacquer may be applied with a spray gun or with a brush. As the alcoholic solvent evaporates, the lacquer leaves a hard, tough film which is little affected by weather conditions. Pigments may be added to lacquers too. [See Fig. 9–9.]

Some of the products which chemists now make out of cotton fibers are so unusual that their story reads like a fairy tale. The cotton fibers are first treated with a mixture of sulfuric acid and nitric acid. If strong, concentrated nitric acid is used, the product formed is made into *smokeless powder*. If the nitric acid used is weaker, or if the time it reacts on the cotton is shortened, the product formed may be used in almost countless ways. For example, it may be spun into threads and used as *rayon*, a substitute for silk. It may be fashioned into thin sheets for making *Kodak film* or *motion-picture film*. Under the name of pyralin, pyroxylin, or celluloid it may be made into combs, brushes, toilet articles, novelty articles; or it may become the "sandwich" filling for safety glass. The product may be dissolved in a mixture of alcohol and ether and used as liquid court plaster. The chemical name for the product formed by treating cotton with nitric acid is *nitrocellulose*. It is easily flammable. Hence acetic acid is sometimes used instead of nitric acid. The product formed by this reaction is known as *cellulose acetate*. It is not so combustible as nitrocellulose.

**217. Why are lacquers, paints, and varnishes so important?** One manufacturer of paints uses as a slogan, "Save the surface, and you save all." There are at least three important reasons why varnishes, lacquers, and paints are so important.

*a*) They give a smooth, hard surface which is not too easily marred or scratched. In some cases, they cover up a large number of defects.

*b*) They afford an opportunity to use any desired color, or any combination of colors. For that reason, in selecting lacquer or paint, an artist's opinion is desirable.

*c*) They prevent the decay of wood, and to a considerable extent the rusting of iron. It is true, however, that some paints hasten the rusting of iron. Lampblack is such a paint. If iron work is to be painted black, an undercoat of red lead or zinc orange is first applied to the iron. No doubt you have observed that fire escapes, steel bridges, and iron fences are first painted red or orange before they are given a finishing coat of black.

218. **How shall hardwood floors be finished?** If oak floors are to remain beautiful, they must be properly finished. Since oak is somewhat porous, a paste filler must be rubbed into the surface after it has been scraped and sandpapered. Such a filler may be thinned with turpentine or alcohol, and a little stain may be added if desired. At least twelve hours must be allowed for the filler to dry after it has been rubbed into the pores of the wood. In such manner a foundation is secured for one of the following methods of finishing.

*a*) *Shellac finish.* If shellac is to be used for finishing the floor, at least two coats are needed. Shellac is dissolved in methanol or wood alcohol, or in denatured alcohol. When the alcohol evaporates, the shellac dries in a couple of hours, and forms a hard surface. Because the film of shellac is rather brittle, it wears away rather quickly, and another coat becomes necessary. However, if a thin coating of wax is applied occasionally to shellacked floors, they may be kept in good condition for a long time.

*b*) *Varnish finish.* After the filler has dried, a hardwood floor may be given two coats of a good floor varnish. Plenty of time must be allowed for each coat to dry. The *best* floor varnish costs somewhat more than shellac does, but it wears longer. It is not so easy to patch worn places in a varnished floor as it is one that is finished with shellac. A varnished floor may be waxed, too, to restore its fresh luster, but it is a nuisance to remove wax if the floor needs revarnishing.

*c*) *Wax finish.* A floor may be finished merely by applying some kind of floor wax after the pores of the wood have

been filled. The wax needs a few minutes in which to dry, and it is then rubbed to a fairly high polish by means of a weighted brush. Two coats are applied. The cost of a waxed floor is rather low, and it can be kept in good condition by rewaxing it from time to time. Some "brushless waxes" are used. Floors made of birch, maple, or comb grain pine are usually finished by waxing them or by the use of two coats of a good *spar varnish.*

**219. What is linoleum?** In the manufacture of linoleum, boiled linseed oil is permitted to flow slowly over long strips of cotton *scrim* suspended vertically. Oxygen is slowly absorbed by the oil, and a film is formed. The flooding continues slowly until the film that is built up measures about an inch in thickness. Then the strips of cotton are torn down, and the thick film formed from the oil is ground up with powdered cork, rosin, and kauri resin. That forms the *linoleum batch.*

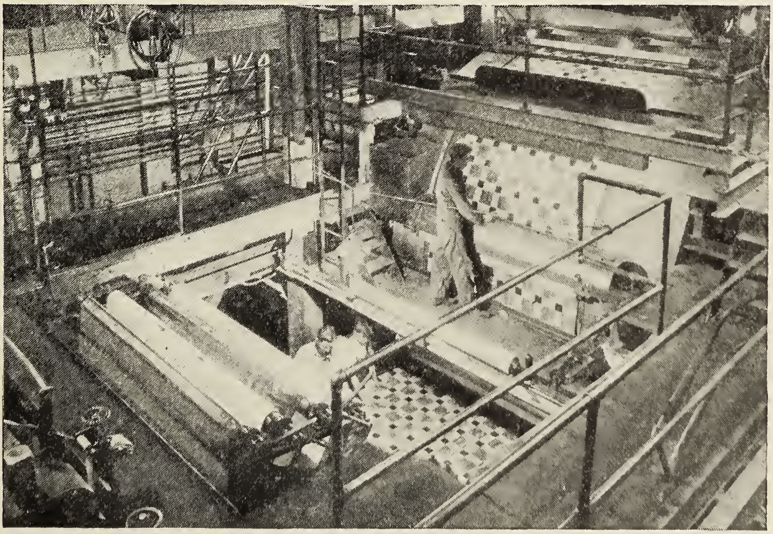


FIG. 9–10. This huge machine is used for making inlaid linoleum. The machine cuts out pieces of different colors, places them to make the design, and rolls them down upon burlap. (*Courtesy Armstrong Cork Co.*)

The linoleum mixture, or batch, is then rolled down upon a piece of burlap in order to make the linoleum of commerce. Pigments may be added to the batch to give any desired color. *Inlaid linoleum* is made by cutting out pieces of various colors, fitting them into the design, and then rolling them on burlap by means of heavy rollers. The old hand method employed a stencil, over which the powdered linoleum was sifted into the design. The modern machine for cutting out the pieces, fitting them into the design, and rolling them is a huge affair more than two stories high. [See Fig. 9–10.]

**220. Linoleum as a floor covering.** The advertisers suggest linoleum for every room, but most persons find it a more popular floor covering for the kitchen and the breakfast room. It may be used to cover a cheap wooden floor. As a rule, the linoleum is firmly cemented to such a floor. Linoleum is very durable, and it is not easily affected by corrosive liquids. Linoleum is easily kept clean. It may be varnished occasionally to restore its luster.

Some linoleum patterns are so attractive that they are substituted for rugs and carpets. In the form of imitation tiles, linoleum is used as a floor covering for porch floors, sun parlors, and other rooms.

**221. How shall we finish the side walls and ceilings?** When mortar and plaster harden, they take carbon dioxide from the air, and they give off water. For that reason the walls of freshly plastered houses remain damp for some time. It actually takes years for the plaster to become completely hardened. If walls and ceilings are to be painted or plastered, it is a good idea to let them stand unfinished for a year or more to permit them to dry more thoroughly before the paint or plaster is applied.

Styles in the finishing of walls change almost as frequently as do the styles of women's hats. Sometimes it is the fashion to finish walls with certain waterproof plasters, either finished in solid color or by the use of harmonizing tints. Such walls are generally left with slightly roughened surfaces.

It is a matter of taste whether walls shall be painted or papered. Many persons feel that wallpaper gives to a room a somewhat warmer tone than do painted walls. Many of the modern wallpapers are waterproof and can be sponged without injury. It is in good taste to paint the ceilings of a room with a light-colored flat paint, and then use paper on the side walls. One needs to remember that a wallpaper with large, scrawling figures makes a room seem smaller than does a plain or a small-figured paper. One needs to remember, too, that yellows or light tans may be better for north rooms than are blues and greens.

If the side walls and the ceilings are both to be painted, the ceilings should always be painted a slightly lighter tint than that used for the side walls. The question of gloss and smoothness must be considered, too. A glossy finish is more easily kept clean, but it produces glare. A too-flat finish soils easily and is harder to wash. Many persons compromise on an eggshell finish, which is about as lustrous as a newly-laid egg. It does not glare too much, and yet it has enough gloss to enable it to be cleaned rather easily. A *stippled* finish prevents glare by scattering or diffusing the light in all directions.

**222. How shall we finish the woodwork?** If the woodwork trim is of oak, or of chestnut, it may merely be filled with a paste and then waxed. Dark-colored doors of birch or mahogany may be treated in a similar manner, or they may be varnished.

Many persons prefer to have the door frames, the window casings, the baseboard, and the molding painted some light color. If varnish is added to the paint, or if enamel is used, the surface will be harder and it will soil less easily. For the living room and the dining room, a nearly flat finish coat is pleasing. For the kitchen and pantry, a slightly more glossy coat is desirable. Here the woodwork may be given two coats of flat paint and then two coats of enamel. Such a paint job wears well and may be scrubbed without much injury.

Floors and woodwork are sometimes painted or finished with dark colors, but almost invariably they give the rooms a gloomy appearance which can hardly be overcome by any brilliancy of color used for draperies or decorations.

## QUESTIONS

1. Are there any fire hazards around your home? If so, what can you do about them?
2. What do you understand by the term *complementary colors?*
3. What is meant by the term *harmonizing colors?*
4. Of what do all paints consist? What other substances are sometimes added to paints?
5. What is the purpose of a thinner when added to a paint?
6. Is it possible for a painter to be poisoned by the use of white-lead paint?
7. Try to find out whether workmen in white-lead factories ever suffer from lead poisoning. Make a report to class on the subject.
8. One large firm which manufactures paints has an advertising slogan stating that those paints cover the earth. Do you think that this advertisement can be justified? Explain.
9. Why are lacquers important?

## SOME THINGS FOR YOU TO DO

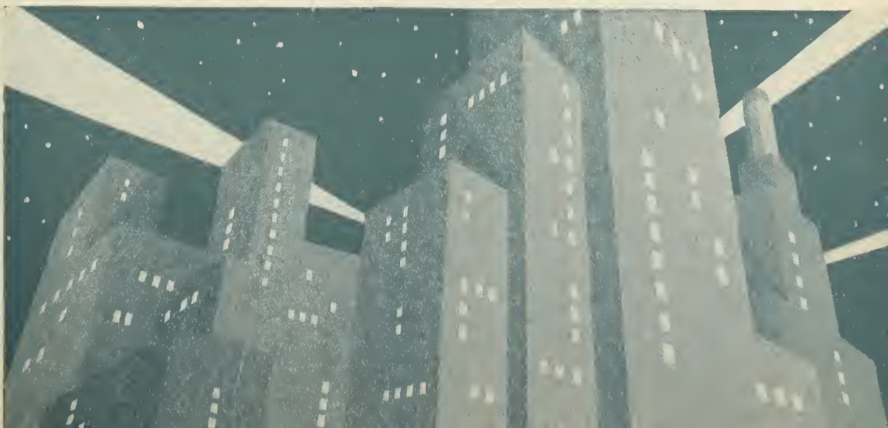
1. Upon a large sheet of paper draw the floor plans of a house in which you think you would like to live.
2. Draw a detailed floor plan for a kitchen. Place the kitchen furniture in the plan in such a position that few unnecessary steps would need to be taken by a person working in that kitchen.
3. Make a list of the things you think could be done to make your present home more livable. Try to form an estimate, with the help of your parents, of the cost of the changes that you suggest.
4. Plan a color scheme for the rooms in your home, and make a list of the colors you would use in each room.

# We Are Making More Effective Use of Light Energy

If man were to make a list of the free things with which he is supplied, he would not go far wrong in putting sunlight at the top of the list. Scientific invention or discovery has produced no perfect substitute for sunlight.

Light is a form of energy. In the daytime we utilize the light energy from the sun. At night we must depend upon artificial sources for the illumination of our homes, stores, and factories. If we could have 600,000 full moons suspended in the sky at night, then we would not have to depend, to a very great degree, upon candles, oil lamps, or electricity for light energy. We realize how important such light is to us when we are deprived of it. A "blackout" in a war zone helps to protect the citizens against deadly bombs, but exposes them to other inconveniences and dangers.

One of the problems in home lighting consists in getting light energy where it is needed. The amount of light needed by a person depends upon the kind of work he is doing.



In the following chapter on light, we shall also study some of the methods used to form images. Such images may be enlarged, or they may be reduced in size. They may be thrown upon a screen for the education or the entertainment of a large number of persons at one time. Telescopes are made to catch larger amounts of light from heavenly bodies and make them seem closer to us, and the compound microscope enables us to see the objects which without its use would be invisible to us. Man has also learned how to use eyeglasses to correct his defective or failing vision. Man has learned a great deal about the effects which light produces, but he is still rather ignorant of the nature of light itself.

## *Think about these!*

1. Where does daylight come from? How does it reach you? How fast does it travel?

2. Is the lighting of your home efficient? Is your home economically lighted?

3. What do you really mean when you say that one object is red and another one is blue?

## *Words for this chapter*

**Resistance.** Opposed to motion; opposition.
**Fluorescent.** Glowing with a rather pale, soft light.
**Luminous.** Shining from its own light.
**Illuminated.** Shining because it reflects part of the light that falls upon it.
**Translucent.** Permitting light to pass through, but not readily enough for one to distinguish objects through it.
**Distorted.** Pressed or pushed out of shape; misshapen.
**Carbonize.** To heat until charred.


CHAPTER 10 ______________ UNIT 5

# Why Is Light Energy a Boon to Man?

**223. Where does light come from?** When Shakespeare wrote, "Night's candles are burnt out, and jocund day stands tiptoe on the misty mountaintops," he was merely stressing in poetical language the importance of our sun as a light bearer, when compared to the myriads of stars that shine by night. You have learned that the sun is our chief source of heat. It is also our chief source of light. Even the light of the full moon is only light that is reflected from the sun. Some of the stars actually give off more light than our sun, but they are so far distant that the amount of light we receive from them is very small.

**224. How can man produce light?** There are two important ways in which man produces light.

*a*) *By burning some substance. Burning* has been defined as rapid oxidation which takes place so quickly that both heat and light are produced. In the use of candles, torches, lanterns, and oil lamps, the light is produced by burning

some material. Some of the light from a burning candle or torch is due to the fact that particles of unburned material are heated until they glow.

*b*) *By heating some substance until it glows.* If we hold one end of a stove poker in a bed of live coals, the poker soon becomes heated white hot. It glows and gives off light. In the electric bulb there is a filament of tungsten wire. When the electric current passes through the tungsten wire, the *resistance* which it meets is so great that much of the electrical energy is changed into heat energy. Part of the heat energy is changed into *light energy.* Our incandescent lamps give us light from a filament that is heated until it glows. [See Fig. 10–1.]

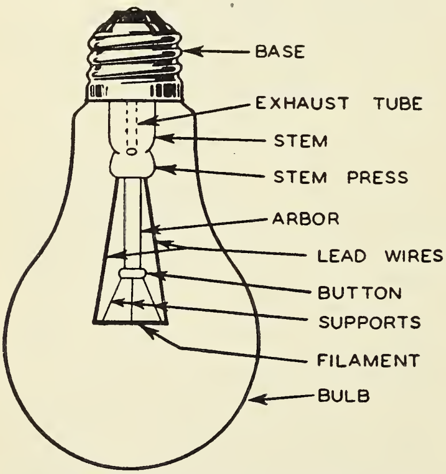



FIG. 10–1. The practice in modern lighting changes so fast that it is difficult to say how soon one type of lamp will be replaced by a better type. It appears now that the electric bulb, here represented, may soon become obsolete, since glow tubes are being used more and more for lighting.
(*Courtesy Westinghouse*)

In some modern *fluorescent* lamps, an electric current flows through a gas enclosed in a tube and causes the gas to become luminous.

**225. How fast does light travel?** Years ago men thought that light does not take any time to travel from one place to another. But careful measurements show that light is not instantaneous, although it does travel at terrific speed. Several methods have been devised to measure its great speed.

The most accurate method ever devised was worked out by A. A. Michelson, who was at that time a professor of physics at the University of Chicago. He constructed a vacuum tube which was one mile long. He then reflected light back and forth through the mile-long tube ten times, using rotating eight-sided mirrors to produce the successive reflections. From the speed at which the mirrors were rotated, he could calculate the time required for light to travel the length of the tube. In that manner he calculated the velocity of light to be 186,285 miles per second. That is believed to be not more than one mile in error. An error of one mile may seem to you to be rather a large one, but it does not seem so large if we consider that the error is only about one-third of an inch for each mile. Do you think you can measure off one mile with a ruler and make an error of less than one-third of an inch? Even the most accurate measurements that man can make are not likely to be absolutely correct.

**226. How do various bodies differ in regard to light?** If a body gives off light from its own light energy, we call it a *luminous body*. If a body shines because it receives light from some outside source, we call it an *illuminated body*. We find that bodies behave in three different ways when they are illuminated by a light of any kind.

*a*) *Some are transparent.* Such bodies as air, water, and clear glass let nearly all the light they receive pass through them. Enough light passes through them so that one can see through them clearly enough to recognize objects on the opposite side. Such bodies are said to be *transparent*.

*b*) *Some are translucent.* Some bodies permit a considerable amount of light to pass through them, possibly enough to light a room. Frosted glass windows or electric globes, and parchment or silk lampshades are examples. But not enough light passes through them to enable us to distinguish objects through them. Such bodies are said to be *translucent*.

*c*) *Some are opaque.* If little or no light passes through a body, we say that it is *opaque*. Such bodies cast *shadows*,

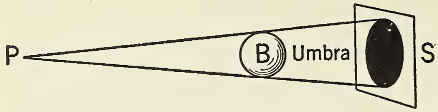



FIG. 10–2. Light which comes from the point P is cut off by the opaque ball at B and forms the umbra at S.

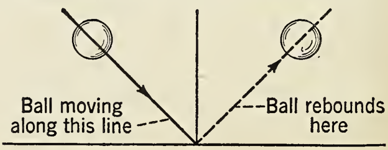
because they cut off the light from that area which is directly opposite to the light source. [See Fig. 10–2.]

**227. What happens to the light that falls upon a body?** We have already seen that much of the light which falls upon a transparent body passes on through that body, or is *transmitted* by it. But we must conclude that some of the light is *absorbed,* because we cannot see so well through even the clearest glass as we can without the glass. The clearest water known absorbs some light, as we can easily prove by looking first through thin layers and then through thick layers. A third portion of the light is *reflected* from the surface of a body. The amount that is reflected will depend upon the smoothness of the surface and the angle at which the light strikes the surface. If you look at the rays of the setting sun as they are reflected from the surface of a body of water, you will realize that some surfaces reflect much of the light they receive.

We conclude, then, that transparent and translucent objects *reflect* some of the light that falls upon them; they *absorb* some of it; and they *transmit* the remainder. Opaque objects *reflect* some of the light that falls upon them, and they *absorb* the remainder.

**228. How is light reflected?** You were not very old when you learned that a ball rebounds after it is thrown against a hard surface. You were a little older when you learned that if you wish to catch such a ball, you must notice the angle at which it strikes the surface and the angle at which it rebounds. [See Fig. 10–3.]

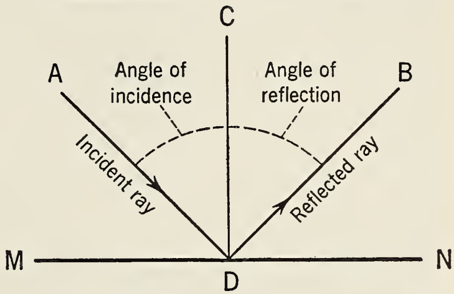
FIG. 10–3. The two angles to the perpendicular are equal.



It may not astonish you very much to learn that light behaves in a similar manner, because you have probably demonstrated such reflection of light by holding a piece of mirror at such an angle in the sunlight that it reflected the sun's rays into someone else's eyes.

Let us refer to Figure 10–4 to show how light is reflected from a plane surface. A single ray of light, coming along the

FIG. 10–4. Both sound and light may be reflected, or made to rebound, from a smooth surface. Note that the two angles are equal.




direction AD strikes a mirror at the point D. We first draw a perpendicular CD to the mirror surface from the point D. The light is reflected from the mirror along the line BD. The angle ADC, which is known as the *angle of incidence,* is exactly equal to the angle CDB, which is called the *angle of reflection.* If we increase the angle of incidence, the angle of reflection increases correspondingly.

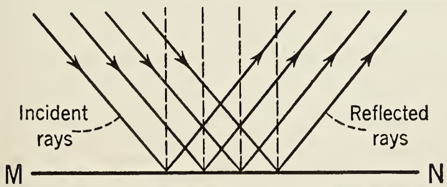



FIG. 10–5. Parallel rays from a plane surface are still parallel when reflected.

If we have several parallel rays of light falling upon a mirror, they will all be reflected from the mirror along parallel lines. [See Fig. 10–5.] That kind of reflection, from smooth surfaces, causes *glare.*

**229. How can glare be prevented?** Suppose that several parallel rays of light fall upon a *roughened* surface. They are

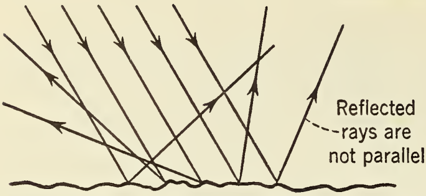



FIG. 10–6. An irregular surface causes a scattering of the reflected rays.

reflected as shown in Figure 10–6. They follow the same law of reflection of light that we learned in the preceding section, that the angle of reflection is equal to the angle of incidence, but the perpendiculars are not parallel to one another. Hence the reflected rays are scattered in all directions. Such diffusion of light is of the greatest importance, because it prevents glare. Without diffusion, the corners of a room would get no light at all, and places directly in front of the windows would glare enough to blind one looking in that direction.

To promote diffusion by reflection, we use the following methods. The walls, ceilings, and the floors of rooms are slightly roughened or covered with paper or paint in order to diffuse light and prevent glare. The paper in this book is not so highly glazed that it is difficult to read. Halftone pictures reproduce more clearly on glossy paper, but book manufacturers sacrifice to some extent the appearance of such pictures by using a semi-gloss paper to promote easy reading.

The tiny dust particles in the air also help to scatter light and promote diffusion. If there were no dust particles to scatter light, it would be almost entirely dark under shade trees. We would find it difficult to see anything, because anywhere we might look there would be glaring spots of light or sharp shadows.

**230. Can transmitted light be diffused?** To answer this question, we may compare the amount of glare that we get when we look at the light from a 60-watt clear-glass light bulb with that which we get from a 60-watt frosted-glass bulb. Translucent glass is now much used in lighting. It is used, too, in the glass walls of some modern houses and factories. [See Fig. 10–7.]

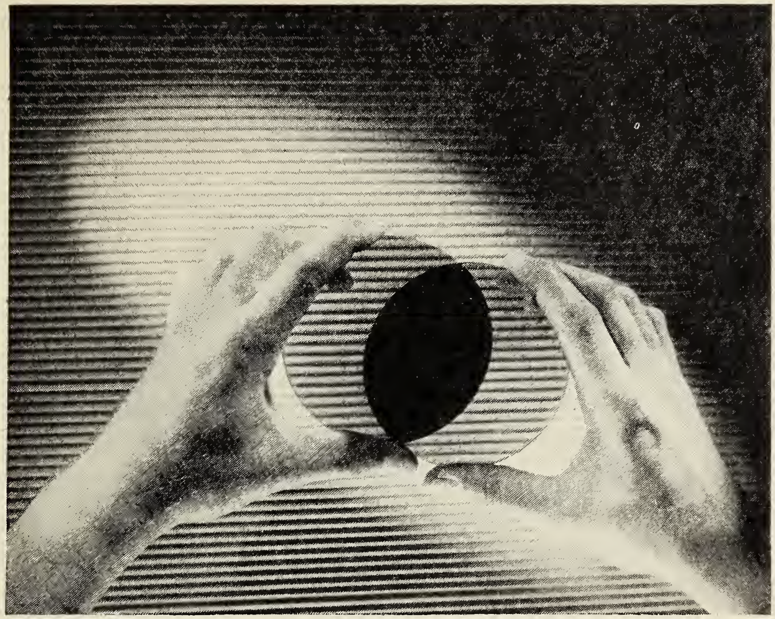


Fig. 10–7. Two glasses made of the material known as *Polaroid* become opaque to light when they are placed together. (*Courtesy of Polaroid Corp.*)

Fig. 10–8. Note the hazy appearance of the highway on the left as it is seen without Polaroid glasses. The same road at the right when glare is eliminated. Suppose the windshield of your car were made of Polaroid, and also the headlight lenses of the car approaching you; how would such an arrangement reduce glare? (*Courtesy of Polaroid Corp.*)

Parchment lampshades and translucent silk shades are used to help in diffusing transmitted light. Manufacturers are attempting to make headlight lenses for automobiles that will prevent the blinding of an oncoming driver by the glare of powerful lights. [See Fig. 10–8.]

231. **What is a mirror?** Any polished surface may serve as a mirror. You have read of Narcissus, who was too well-pleased with his reflection in a pool of water. As a punishment for his vanity, he pined away after gazing too long, and was changed into the flower that bears his name. Some persons have more incentive to look into a mirror than others have, but try looking into a plane mirror long enough to find the answer to the following questions.

*a*) Is your image directly in front of you, on a perpendicular to the plane of the mirror, or is it off to one side?

*b*) Does your image seem to be the same distance behind the mirror that you are in front of it, or does your image appear nearer or farther?

*c*) How does the size of the image compare with your size? Is it smaller than you are? Is it larger? Does it appear to be of the same size?

*d*) Does it appear to be right-side-up or upside-down? Does it seem to be reversed so that your right side seems to be on your left, and vice versa?

*e*) Do you get about the same impression when looking at your image in a mirror as you do when you look at your own photograph? Suppose you write down on paper the answer to all these questions and then check them the next day in class.

232. **For what purposes are mirrors used?** One of the important uses of mirrors is to enable persons to see how they look. Mirrors are useful, too, for flashing signals. Automobile drivers use a mirror to observe whether a car is following and to judge how far behind a following car may be.

Curved mirrors are used to reflect light and to direct most of it in a certain direction. The curved mirrors which form

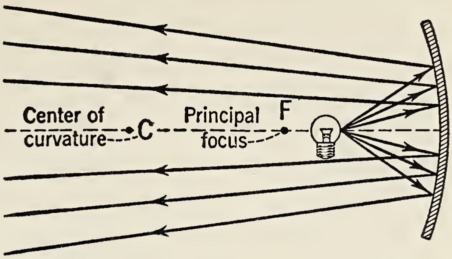



FIG. 10–9. A lamp may be placed so that its rays reflected by a curved mirror are only slightly divergent.

the back part of automobile headlights furnish an excellent example. [See Fig. 10–9.] Curved mirrors are also used in reflecting telescopes to gather a large number of light rays and focus them to form a small, bright image. A curved mirror is used to gather light rays for illuminating an object which is to be magnified by a compound miscroscope. A combination of convex and concave mirrors is used to form *distorted* images. One finds such mirrors in amusement parks. A peep into such a mirror may appear to take off pounds, or it may make a thin man look enormously fat.

**233. How is light measured?** No doubt you have observed that some standard of comparison is needed for any kind of measurement. The standard used for measuring the intensity of a light is the *candle power.* A number of years ago scientists measured the intensity of a light source by comparing its brightness with that of a candle of definite size, and burning at a given rate. Now electric bulbs are made and *standardized* for use in measuring the amount of light a luminous body is emitting. A 20-candle-power lamp gives off as much light as 20 standard candles.

The electric bulbs which you buy are nearly all rated in watts. A 25-watt bulb gives about 20 candle power (C. P.) of light. The 100-watt bulbs give about 100 C. P. of light, or about one candle power for each watt of electrical power that is used. Some of the new gas-filled bulbs are even more efficient, especially the larger-sized ones.

**234. How is the amount of light one receives measured?** The distant stars have billions of billions of candle power.

They are so far away, however, that we do not get as much light from them as we do from one tiny candle which is only one foot distant from us. The amount of light that one receives from a light source must depend upon two things.

a) *The candle power of that light source.* The greater the candle power, the more light it yields.

b) *How far distant the observer is from that light source.* The light spreads out in all directions from the light source. [See Fig. 10–10.] The amount of light that one receives is

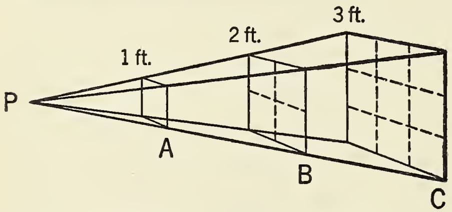



FIG. 10–10. The farther diverging rays of light travel, the larger the area they must illuminate. The intensity of light at C is only one-ninth that at A.

measured by the unit called the *foot-candle. This unit is defined as the amount of light an object receives at a distance of one foot from a light source of one candle power.*

If you are one foot distant from a light of one candle power, you receive one foot-candle of light. If you are one foot from a light of five candle power, you get five foot-candles of light. It has been shown, however, that a person who is *two feet distant* from a light of one candle power will receive only one-fourth of a foot-candle of light. *Doubling* one's distance from a light source cuts the amount of light he receives to just *one-fourth* the amount he received before. If he moves to a distance *three* times as far away, he will receive only *one-ninth* as much light as he did before moving. The amount of light received by an object decreases as the *square of its distance* from the source increases.

**235. How much light do we need?** Illumination engineers do not all agree on the number of foot-candles a person needs for various kinds of work. In recent years, they are giving a larger number as necessary for rapid and efficient

work than they did a few years ago. Formerly, engineers considered that three or four foot-candles of light were sufficient for reading ordinary print. Now they are more likely to recommend the following.

In order to read ordinary print, of the size used in this book, one should get at least 6 foot-candles of light. For reading a closely printed page of smaller type, from 10 to 15 foot-candles, at least, are needed. If one is sewing on black goods, with fine thread, at least 20 foot-candles are required. Black absorbs much light, and for that reason one must have more foot-candles for work on black material than he does for work on white material.

As a result of experiments, it has been found that better factory illumination not only speeds up piecework, but it also decreases the number of accidents. When our highways are all lighted, we may expect to see the number of night automobile accidents decrease decidedly. Glare must be eliminated, too, and sharp shadows reduced by the proper diffusion of light. [See Fig. 10–11.]

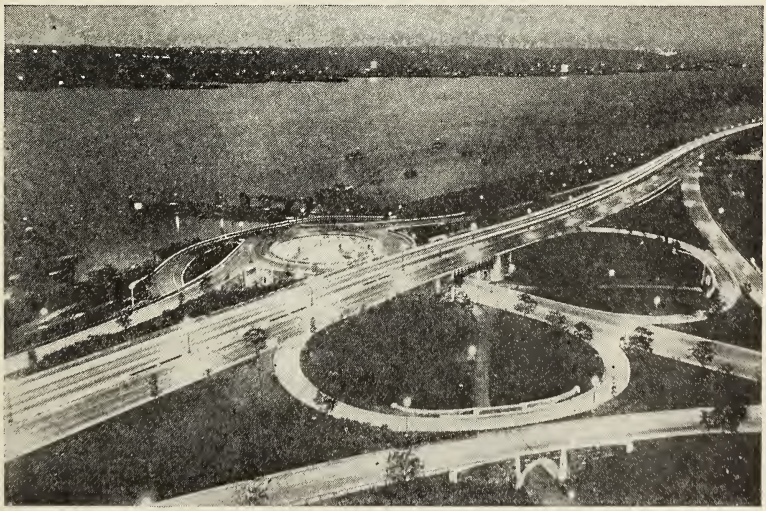


FIG. 10–11. The illumination of highways tends to prevent accidents. (*Courtesy New York City Park Department*)

**236. How can we economize on our light bill?** One would not show much common sense if he were to build a tremendous fire in the fireplace and make it so hot that everyone would be forced to move back some ten feet or more. It shows just as poor judgment for a person to buy a 200-watt electric bulb and place it a few inches below the nine-foot ceiling of a small reading room. Then it will be about six feet distant from a table at which you may be working. There are two ways in which a person can get the number of foot-candles he requires for his work. He may use a high candle-power electric bulb, or he may move close to the light. Which is more economical? Naturally, the latter. The first method costs more money because we pay for electricity in terms of the number of watt-hours of energy consumed. Five 200-watt bulbs burning for one hour will consume 1000 watt-hours of electrical energy, or one *kilowatt-hour* of energy. The price of electrical energy varies in different localities, but it generally runs from 3 cents to 12 cents per kilowatt-hour.

If a person reads by the light of a 200-watt bulb at a distance of 6 feet, he is getting a trifle less than 6 foot-candles of light ($200 \div 6^2$). If he reads from the light of a 40-watt bulb at a distance of 2 feet, he will receive about 8 foot-candles of light. In the first case, it is costing him five times as much as it does in the second case. If you wish to be economical, you will forget the quotation from Shakespeare, "How far that little candle throws his beams!" and take for your slogan, "Come hither, tiny candle!"

**237. How has artificial lighting progressed?** In our early colonial days, the candle, or the tallow dip, was in common use for lighting houses, just as it had been for centuries. Oil lamps, too, had been in use for many centuries. The old Romans used a lamp of stone, or of brass, hollowed out to contain some kind of oil. One end of a twisted wick of cotton or linen was then stuck into the oil, and the other end was lighted. It burned with a rather smoky flame.

In about the year 1850 kerosene began to be sufficiently

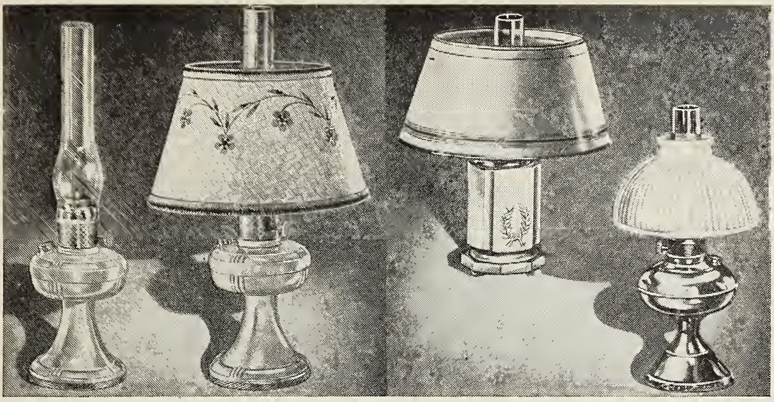


FIG. 10–12. These lamps of the past were considered excellent when kerosene was an important illuminant. (*Courtesy Montgomery Ward*)

refined to be useful for lighting. At that time it came into extensive use for illumination, and it is still used in houses not fitted with either gas or electricity.

The kerosene lamp, too, has been much improved since the time when it was invented and came into common use. The Rochester burner, with its circular wick, gives a soft light suitable for general use. Air enters through holes in the base and rises through the tube surrounded by the circular wick. There it unites with the kerosene which is drawn upward by the action of the wick and burns with a clean, steady flame. The additional air which is needed for complete combustion enters around the sides of the wick through tiny holes in the burner, which not only holds the wick, but also supports the chimney. The waste gases formed by the burning kerosene escape from the top of the chimney.

Gas lighting came into common use, especially in cities, around 1875. A flat flame was in use when Dr. Auer von Welsbach invented the gas mantle. Such a mantle was made by dipping cotton or rayon into a solution of the nitrates of cerium and thorium. Then when the mantle was heated, the oxides of these metals were formed. They may be heated to a

very high temperature without melting. When the gas was turned on and lighted, the mantle glowed with a fine, white light. The use of gas with a mantle gave an efficient light. Such mantles could be used with gasoline or kerosene lamps if special fixtures were also used.

238. **Of what does the electric bulb consist?** The story of the incandescent light bulb is a romantic story of man's persistence. It is also an excellent example of the use of the scientific method. The idea called for some kind of thread or filament through which the electric current would pass with difficulty. In fact, the friction or resistance offered to the current would have to be great enough so that the filament would be heated almost white hot. The problem was to find some material for such a filament. That material required was one that would be flexible, would have a high melting point, and would not evaporate to any marked degree.

Just a few years ago the celebration of the fiftieth anniversary of the invention of the electric incandescent lamp by Thomas A. Edison was held in Orange, New Jersey. Roselle, in New Jersey, was the first town to be lighted by electricity. Now we find electric light even in country places where it is necessary for the owner to generate his own electricity. The "light in a bottle," as it has often been called, has been improved from time to time. [See Fig. 10–13.] It can be truthfully said that this invention by Edison has revolutionized home and street lighting throughout the civilized world.

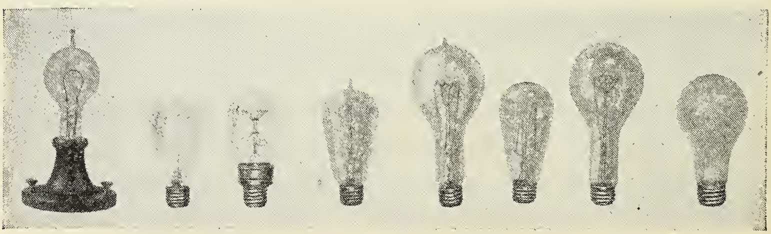


FIG. 10–13. The varying types of lamps show progress in lighting. (*Courtesy General Electric Co.*)

Edison sent men all over the world in search of some material for use as a filament. He knew that carbon melts at the very high temperature of about 3500°C., and that it evaporates very slowly even at high temperatures. He heated many different fibers in an oven to *carbonize* them, or to drive off by the heat all the elements in the fiber except the carbon. He even carbonized a hair from the red beard of one of his helpers. For two years the search continued before it was found that carbon made from a certain kind of bamboo fiber was sufficiently tough.

But carbon burns when heated in air. Then Edison decided to put the filament in a glass bulb and pump out all the air from the bulb so that no burning could take place inside the bulb.

Then another problem arose. The ends of the filament had to be connected to the electric wires outside the bulb. To make such connections "lead-in" wires had to be sealed

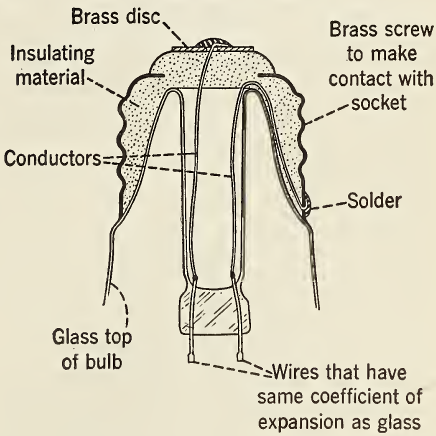



Fig. 10–14. Wires which serve as conductors must be sealed into the glass of an electric bulb.

in the glass bulb. [See Fig. 10–14.] Copper wires cannot be used for such a purpose, because copper expands more than glass does when heated, and it contracts more when cooled. Hence copper wire cannot be sealed in glass to make an airtight joint. In the first lamps that were made two short pieces

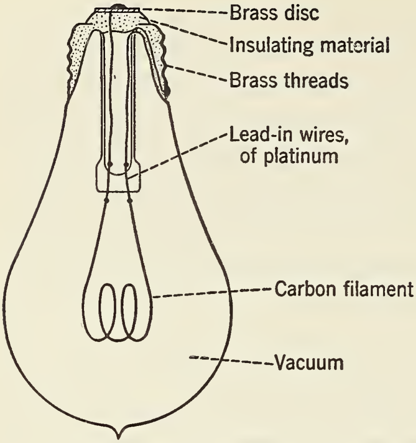



FIG. 10–15. At one time this "light in a bottle" was considered a real wonder. Now we can get better light by the use of electricity at a cost of not more than one-sixth of that used for operating an old carbon lamp such as this one.

of platinum wire were used for the "lead-in" wires, because platinum expands at the same rate that glass does. [See Fig. 10–15.] These early Edison lamps were fairly good, but man is never satisfied.

239. **How have incandescent lamps been improved?** The search for a better filament than carbon continued. The metal *tantalum* was tried with some success. Then it was learned that wire can be made out of *tungsten*, a silver-white metal. Fine tungsten wire offers enough resistance to the current to be heated white-hot by it. Tungsten melts at about 3000°C., and it evaporates very slowly, even at a high temperature. Drawn tungsten wire is not very brittle. Tungsten proved so successful that the filaments for nearly all electric bulbs are now made of that metal. The tungsten filament is superior in the following ways.

*a*) The tungsten filament gives a whiter light than the carbon filament does. It is more like sunlight. In fact, one manufacturer uses the name "Mazda" for his lamps, since that, as you may remember, was the name of the Persian sun god.

*b*) The old carbon-filament lamp gave only one candle power of light for about 3.5 watts of electrical power. Some of the most modern tungsten filament lamps give one candle

power for slightly less than one watt of electrical power. It is estimated that the substitution of the modern tungsten lamp for the older carbon lamp has resulted in saving the people of the United States at least a billion dollars a year in electric-light bills.

As the result of a great deal of research work, an alloy of the metals nickel and iron, known as *dumet,* has been made. This alloy expands at the same rate that glass does. Thus, instead of the very expensive platinum, dumet is now used for the " lead-in " wires of bulbs.

The bulb has been improved, too. The old, elongated bulb, which gave high candle power in horizontal directions and low candle power in a downward direction, has been replaced by the present pear-shaped bulbs. The tip of glass used for pumping the air out of the bulbs is now inside the bulb beneath the screw cap.

At one time clear glass was used for the bulbs.. To reduce glare, they were then partially frosted on the outside. Then complete frosting followed. Now most bulbs are completely frosted on the inside to diffuse the light. The outside surface is smooth and can be easily kept clean.

It was found, too, by experiment, that electric bulbs are more efficient if the air is pumped out, and the bulb filled with a mixture of nitrogen and argon gases. Neither of these gases unites with tungsten. The increased efficiency arises from the fact that the filament can be heated hotter in a gas-filled bulb than it can in a vacuum bulb. The gas molecules get in the way of the tungsten molecules that are trying to evaporate. These gases get their jobs " for doing nothing and getting in the way." If much tungsten evaporates, it accumulates on the inside of the glass and darkens it.

The suspension of the filament, too, has been improved. The modern filament consists of a coil of wire, so suspended that the light will be concentrated near the center of the bulb.

**240. How shall we plan our home lighting?** A number of years ago, it was common practice to have a central light-

ing fixture of four or five bulbs suspended from the center of the ceiling of the living room. Electric wall " candles " are now more common, since they give a better distribution of light. They are generally supplemented by floor lamps, for use in reading or for other purposes where the light needs to be brought nearer to one's work. The so-called bridge lamps, which can be raised or lowered on a standard, are very satisfactory.

In the dining room, a center light may be swung fairly low over the dining-room table. Not much light is needed in other parts of the dining room. Wall " candles," or a pair of real candlesticks on the buffet, are sometimes used for their artistic effect.

Many kitchens have a central light, of rather high candle power, placed a few inches below the ceiling. Such a light gives good illumination of the cupboards. A wall lamp over the range and one over the sink serve to concentrate the light where it is most needed.

In some bedrooms a central lighting fixture is used for fairly general lighting. Electric candles on the dresser, or on the dressing table, are lighted from convenient outlets in the baseboard. Reading lamps are sometimes attached to the headboard of the bed, but the habit of reading in bed may not be good for the eyes.

A single center lamp gives general light for the bathroom. Two bulbs, one on either side of the shaving mirror, are much better than a single bulb placed just above the mirror.

**241. What type of lighting shall we use?** Several different types of lighting are in use.

*a*) *Direct lighting.* In this type of lighting, the light shines directly upon one's work. It is efficient because little light is wasted. To keep the light from shining directly in one's eyes, a lamp shade must be used. A shade increases the efficiency, too, since it reflects those rays of light that would normally travel upward or sidewise so that they fall downward upon the object that one wishes to have illuminated.

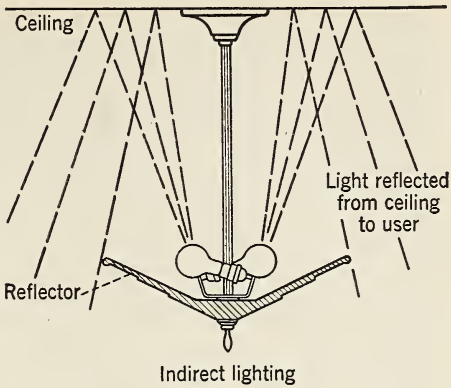



FIG. 10–16. Such indirect lighting gives a soft, agreeable light, free from glare. It is less efficient, however, than some other types.

*b*) *Indirect lighting.* In indirect lighting, all the rays of light are first reflected to the ceiling by an opaque reflector. [See Fig. 10–16.] It gives very soft lighting effects, suitable for auditoriums. However, since much light is wasted in this type of lighting, it is not very efficient. The ceilings should be light in color, so that they will absorb as little as possible of the light which they receive, but will reflect the greater part of it.

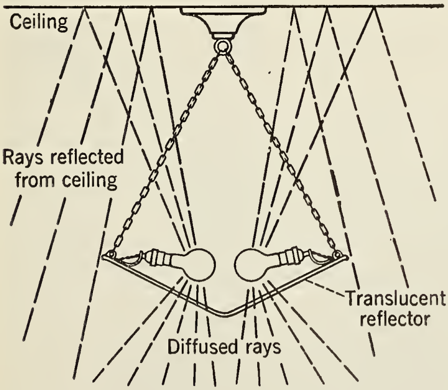



FIG. 10–17. Semi-indirect lighting gives soft light, too, and it is more efficient than indirect lighting.

*c*) *Semi-indirect lighting.* The diagram of Figure 10–17 shows the principle used in semi-indirect lighting. The reflector is made of translucent glass. Some of the rays filter through the glass to the space below, and a part are reflected

to the ceiling, whence they are again reflected to the floors below. This type of lighting is less efficient than the direct lighting system, but more efficient than the indirect. Light-colored ceilings must be used, too, with this type of lighting.

*d*) *Diffusion lighting.* Diffusion lighting finds use in hallways, kitchens, and bathrooms. The rays of light are diffused in passing through the translucent glass globe which surrounds or partially surrounds the light bulb.

*e*) *A combination lamp.* One type of floor lamp that is widely used combines very effectively two or three different types of lighting. There may be two or three small frosted bulbs which can be used for direct lighting, with a shade adjusted to help reduce the glare. Inside a reflector is a large bulb of from 100–150 watts in capacity. The reflector may be opaque to give indirect lighting, or partially opaque and translucent for semi-direct lighting. [See Fig. 10–18.]

*f*) *Floodlighting.* A battery of projectors is often used to cover a building with a flood of light. In normal times, Radio City in New York and the Capitol in Washington are equipped with such projectors for floodlighting them at night.

FIG. 10–18. A room that is excellently lighted for reading. (*Courtesy of General Electric Co.*)

FIG. 10–19. Night baseball is popular in some cities. Eight batteries of 1500-watt floodlights are used to light this baseball diamond and playing field. (*Westinghouse Photo*)

Niagara Falls is illuminated at night with floodlights of varying colors. Baseball fields and football stadiums are often floodlighted to make possible the playing of games at night. [See Fig. 10–19.]

g) *Display lighting.* Many large advertising signs use *neon* lighting. A glass tube may be bent in any direction to spell out words or to outline various designs. Neon gas on the inside glows when electricity is passed through the tube. Different colors are produced by using other gases inside the tubes, or by using different-colored glass for the tubes. The cost of neon lighting is very small. [See Fig. 10–20.] If neon advertising signs are used near traffic lights, they may confuse drivers and become a safety hazard.

Visitors to the New York World's Fair had an opportunity to see glass tubes in use for fluorescent lighting. The inside coating of the tube glows with soft colors which are determined by the coating. Such tubes are economical.

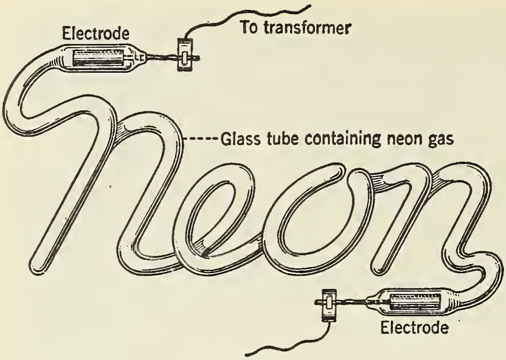



Fig. 10–20. Neon lighting is effective for advertising signs, and it is inexpensive, too.

**242. What is meant by color?** We say that an object is blue. In order for one to see a blue dress, for example, three things are necessary.

*a*) Blue light, or sunshine containing blue light, must be shining upon it. No object can appear blue if only yellow or only red light is shining upon it.

*b*) The object which we call blue must be able to absorb all the various colored lights which fall upon it, except the blue light. It must have the ability to reflect blue light.

*c*) The eye of the observer must be sensitive to blue light. Some eyes are not sensitive to all colors.

We say that some of the stripes in the United States flag are red, because they absorb all the colors of the sunlight which fall upon them except the red and they reflect the red light back to the eye of the observer. An object that is green absorbs every other color except the green, which it reflects to the eye. These statements apply to opaque objects when we speak of their color.

**243. What are sunlight colors?** If you permit sunlight to fall upon a glass prism, you will find that the prism disperses, or scatters, the rays of sunlight. The dispersed rays are separated into seven different colors: violet, indigo, blue, green, yellow, orange, and red. These seven colors are known as sunlight colors.

It is possible to separate or disperse sunlight into its seven

colors by permitting it to pass through drops of water. Such dispersal occurs when sunlight is dispersed by drops of falling water to form a rainbow.

When the seven colors present in sunlight recombine, they form white light again. For that reason we usually speak of sunlight as *white* light.

**244. Are white and black true colors?** If an object reflects back to the eye of the observer all the different colors of sunlight which it receives, the observer calls the object *white*. A *black* object absorbs all the light that it receives. Therefore black is really the absence of color.

No object is entirely black, since everything reflects some light. On the other hand, what may be called the "whitest" object absorbs some light. Dark-colored objects absorb a larger proportion of the light which they receive than light-colored objects absorb. This explains why more foot-candles are needed for a seamstress who is sewing on black goods than for one who is sewing on white goods. It also explains why rooms with dark-colored paper or paint are likely to appear gloomy.

**245. What is the color of transparent objects?** While the color of an opaque object depends upon the color of the light it reflects, the color of a transparent object depends upon the color of the light it transmits. A piece of red glass, for example, absorbs all other colors and lets red pass through it. If we look at the United States flag through a piece of red glass, the blue field will appear black, because blue light is absorbed by red glass. The stars and the stripes will appear red.

**246. What is meant by color blindness?** John Dalton, a Quaker, who was accustomed to wear somber colors, once appeared wearing red stockings. To him they appeared gray. He was color-blind. In other words, he was unable to distinguish one color from another. The most common type of color blindness results in the person's inability to distinguish between red and green. It is estimated that about one man

in twenty or thirty is partially color-blind, but that there is only about one color-blind woman in two hundred.

Tests for color blindness are now given in some states to persons who are making application for a license to drive an automobile. The person who is color-blind must lose a great deal of the beauty in nature, but some of his mistakes are amusing to others. For example, the poet Whittier is said to have patched some damaged green wallpaper with a bright crimson. One boy in a chemistry class said he knew some colors. No one could fool him on yellow; as an example, he pointed to a solution of blue vitriol.

## QUESTIONS

1. How does the moon act like a huge mirror?
2. What is the meaning of the word *incandescent?* How does the word apply to an electric light? To a gas mantle?
3. How accurately do stop watches record time? What fraction of a second is represented by one mile of error in measuring the speed of light?
4. The earth is about three times as far from the sun as is the planet Mercury. Explain why one square foot of land surface on Mercury receives about nine times as much heat and light from the sun as one square foot of the earth's surface.
5. What is a shadow?
6. What is meant by saying that the earth's shadow falls upon the moon at the time of an eclipse of the moon?
7. Why is the diffusion of light important?
8. Do you think that light travels in straight lines, or that it bends around corners? Give a reason for your answer.
9. Why is it easy to read the pages of a newspaper?
10. From your point of view, which unit is more important, the candle power or the foot candle?
11. How can you adjust your reading lamp for economy?
12. Calvin Coolidge said: "Nothing in the world can take the place of perseverance." Do you think that Edison would have agreed with Coolidge?

13. What are some of the reasons why a kerosene lamp may smoke? What is the remedy?

14. The first frosted bulbs made were frosted on the outside. Explain why they are now frosted on the inside.

15. What are the advantages of the combination floor lamp?

16. How does the invention of the incandescent electric lamp illustrate the scientific method of approaching a problem?

17. What are your school colors? Look at them through a piece of red glass. What colors do they appear to be when seen through the glass?

18. How do your school colors appear when seen through a piece of blue glass?

19. A piece of red cloth appears black if light which contains no red rays falls upon it. Explain.

20. Photographers often use a mercury vapor lamp, which has few red rays. A person sitting under the rays of such a lamp appears greenish and ghastly. Why is this so?

21. How is a color-blind person handicapped in driving an automobile?

## *Some things for you to do*

1. In some physics textbook look up the work of Roemer in determining the velocity of light. Give a report in class.

2. Set up a rather large concave mirror at one end of a darkened room. Starting at the opposite end of the room, carry a lighted candle toward the mirror. Make a record of the different appearances of the candle's image as formed by the mirror.

3. Collect a set of squares of glass of different colors. Examine the United States flag, your school colors, and other colored objects by looking at them through the glass plates. Tabulate your results. Try using some combinations of glass plates, such as green and red.

4. Fasten a bright red disc to a sheet of white cardboard attached to a wall opposite the windows of a bright, sunny room. Look fixedly at the disc for at least 40 seconds. Then look at the white paper at a spot a few inches below the disc. What do you observe? Repeat, using discs of other colors. For an explanation, see *Retinal fatigue,* as described in some physics textbook.

## *Think about these!*

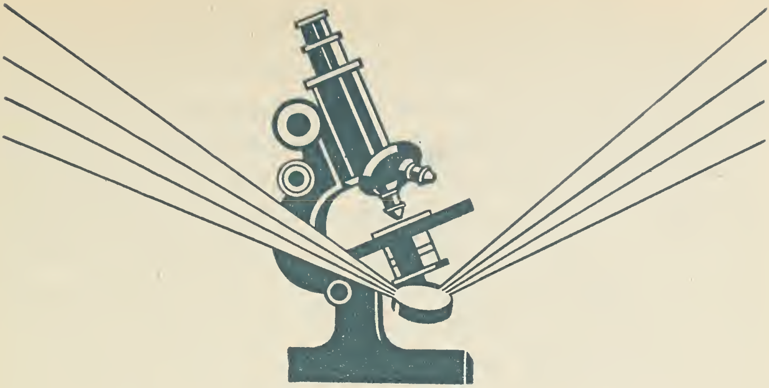
1. Do you think that your eye is an optical instrument?
2. Are the figures in motion pictures really in motion when you see them?
3. Why do persons say, "You cannot fool me. I saw it," and then pay a magician to fool them?
4. Does light always travel in straight lines?

## *Words for this chapter*

**Refraction.** The bending of a ray of light as it passes from one medium into another one of different density.

**Diaphragm** (dī′*ȧ*·frăm). As used in this chapter, a device to regulate the amount of light that passes through a lens.

**Perspective.** Depth of vision.



CHAPTER 11 ______________ UNIT 5

# How Are Optical Instruments Used?

**247. How does man aid his eyes?** We know that man uses a microscope in order to see things that are too tiny to be seen by the unaided eye. We have already mentioned the fact that man uses a telescope to study the planets and to bring into view millions of stars which, though we look a second or a third time, continue to elude the sight of the naked eye. You have probably used a camera to make a permanent record of things of which you want a picture. Possibly you have made a lantern slide with which an enlarged picture can be formed upon a screen. Perhaps you must use glasses to help you to see clearly. In all these ways, man aids or supplements the power of his own eyes.

**248. How does light travel?** Before we can understand how optical instruments work, we must learn how light travels and how it is bent out of its course under certain circumstances. It is rather annoying to have to stand outside the fence of an athletic field when an exciting football game is going on on the other side of the fence. You can hear the

roars of the crowd, because sound bends around corners and up over fences, but you cannot see over the fence. You come to the conclusion that *light travels in straight lines.* We make use of that fact when we use a rifle. Your eye, the front and rear sights of the rifle, and the object at which you are aiming, are all in the same straight line. The light which is reflected from that object travels in a straight line along those rifle sights directly to your eye. If light bent around corners as sound does, we would not have shadows cast by opaque objects.

It is said that a Frenchman who was very short was often annoyed because he could not see over the heads of persons in a crowd. So he placed a mirror at each end of a hollow cane which he carried, setting the mirrors at angles of 45° to the axis of the cane, just as shown in Figure 11–1. Then he

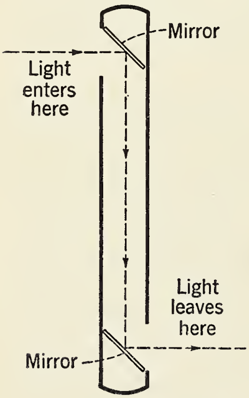
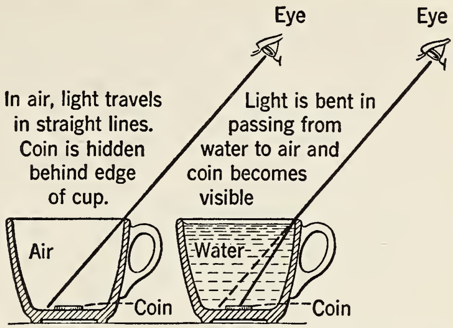



FIG. 11–1. Three small boys discussed the advantages of a third eye and where they would have it placed. The first preferred an eye in the back of his head so that he could watch his teacher. The second suggested the end of his big toe to prevent stubbing his toe. The third won when he suggested an eye on the end of his finger so that he could stick his finger through a knothole and watch the ball game. With the kind of periscope shown here, no third eye is necessary.

could put one end of the cane in front of his eye and use the cane as a simple *periscope* to look over the heads of persons taller than he. The light travels in the direction indicated by the dotted lines.

**249. When does a ray of light bend out of its straight path?** Place a penny in a cup, and then move your head slowly back until the penny is hidden by the edge of the cup, just as is shown in the left side of Figure 11–2. If you

FIG. 11–2. Try the experiment suggested and see whether the penny appears to rise from the bottom of the cup. Light does not always travel in straight lines.




hold your head in the same position while someone pours water into the cup, you will be able to see the penny as it appears to rise in the cup. What happens is that a ray of light coming from the penny is bent at the surface of the water, and then travels toward your eye. See the right-hand side of the figure.

Such bending of a ray of light as it passes from water to air, or from air to water, or from air into glass or vice versa is called *refraction.*

A man sitting on the bank of a stream does not see a fish in its true position in the stream. In Figure 11–3, for example,

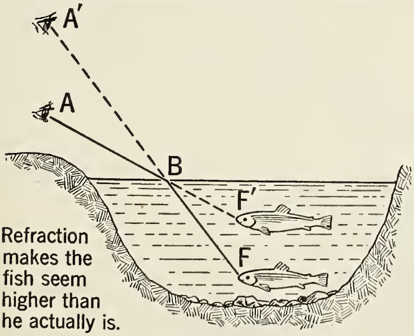



FIG. 11–3. The man whose eye is at A does not see the fish in its true position. On the other hand, the fish does not see the man in his true position. Light rays bend as they enter or leave water.

a ray of light coming from the fish along the line FB is bent as it leaves the water and it travels along the line BA to the eye of the man. For that reason the man sees the fish at F′, at the position shown by the dotted lines.

Neither does the fish see the man in his true position.

Light traveling from the man along the line AB is bent at B and travels to the fish at F. To the fish the man will appear to be at A′, on the dotted line BA′.

If a man wishes to shoot or to spear a fish, he must aim a little lower than the point at which the fish appears to be. The fact that light rays are refracted when they pass from one medium into another of different optical density, often results in confusion, but in a later section we shall see how man uses refraction of light in the lenses which are a part of nearly all optical instruments.

**250. Are there any rules that tell us how light rays bend?** It has been found by experiment that light travels more slowly in water than it does in air. In fact, its speed is only about three-fourths as great in water as it is in air. In glass, light travels only two-thirds as fast as it does in air.

If a ray of light travels at an *oblique* angle (an angle larger or smaller than a right angle) from air into water along the line AO of Figure 11–4, it is bent *toward* the line OD, which

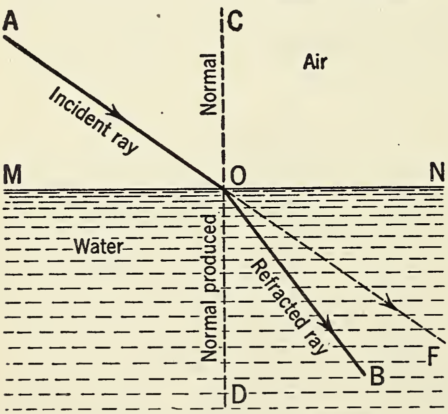



FIG. 11–4. One might expect a ray of light traveling along the line AO to keep on in the line OF, but the ray AO is bent as it reaches the surface of the water, and proceeds along the line OB.

is drawn perpendicular to the surface of the water. That always happens if light passes from one medium into another medium in which its speed is reduced. The bent ray follows the path OB, instead of the dotted line OF.

If a ray of light passes from a piece of glass, for example,

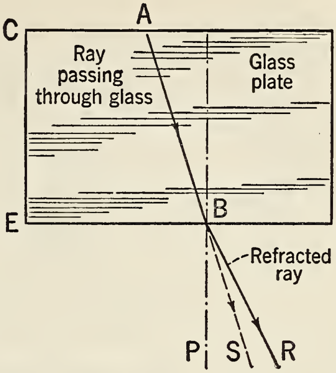



Fig. 11–5. When light passes from glass into air, it is bent away from a perpendicular drawn from the surface of the glass. When a ray of light passes from air into glass, it is bent toward the perpendicular.

into the air, its speed increases, and it is bent *away from* the perpendicular to the surface between the air and the glass. Let us refer to Figure 11–5. The line AB represents a ray of light passing through the glass plate CDEF. As it emerges at B, it does not continue along the dotted line BS, but it is refracted and bent away from the perpendicular BP. The refracted ray of light takes the path BR as it leaves the glass.

**251. Why is refraction so important?** Suppose that we have a *double convex lens,* as shown in Figure 11–6. Such a lens is bounded by two curved surfaces. Let us assume that two parallel rays of light fall upon such a double convex lens made of glass. What happens to them? The ray of light

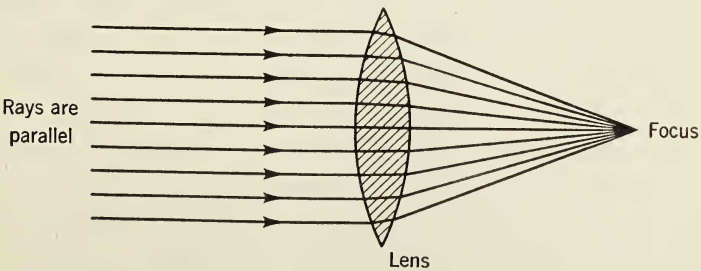



Fig. 11–6. When parallel rays of light fall upon a double convex lens, they are bent so that they meet on the opposite side of the lens at a point called the focus.

traveling along the line AB is refracted as it enters the glass, being bent *toward* the perpendicular to the surface of the glass. It is refracted again as it leaves the glass, being bent *from* the perpendicular and following the line CD.

The ray of light MN is also refracted as it enters, and as it leaves the glass. Its path is represented by the lines MN, NO, and OR. The two parallel lines that fall upon the lens are so refracted that they meet at a point called a *focus*. It is possible for such a lens to receive the rays of light coming from an object and to so refract them that they will form an image of that object. The image may even be thrown upon a screen for study.

**252. How do we use lenses?** The lenses that we use most often are small ones found in our eyes. These lenses produce images upon the *retina*. We use lenses in cameras, too, and in various other optical instruments.

The image that is formed by a lens may be magnified so that it is larger than the object. It may be the same size as the object, or it may be much smaller. The lenses of the eye and the camera both give small, very bright images. The microscope and the motion-picture machine both give very much enlarged images of an object.

If an object is farther distant from the lens than is the screen upon which the image is formed, then the image will be reduced in size, but its brightness will increase. If the object is nearer the lens than is the image that is formed, then the image will be magnified, but it will not be so bright. An image formed by a single lens, when seen on a screen, is always *inverted*, as compared to the object.

**253. Is the eye an optical instrument?** Once in a while you use a magnifier and possibly you have used a compound microscope or a telescope; they are examples of optical instruments. The eye is an optical instrument which a person uses almost every minute of his wakeful hours. Even if one is using a magnifier or a microscope, he is using his eyes at the same time.

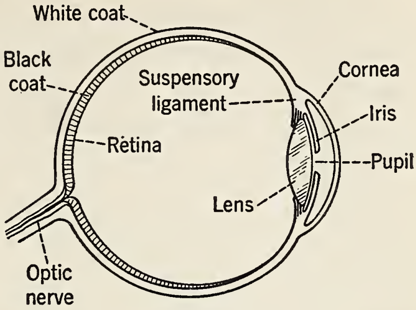



FIG. 11–7. The eye is the most-used optical instrument. The convex lens in the eye forms a tiny image on the retina. Such a lens is self-focusing.

In your earlier study of science you learned something of the structure of the eye. Let us refer to Figure 11–7 as we review briefly the various parts of the eye. The tough outer coat of the eye serves to protect the eye from injury. The middle coat contains a black pigment which absorbs stray rays of light and prevents their being reflected in such a manner that they would confuse the image, just as echoes confuse listeners in some auditoriums. The inner coat of the eye is the black *retina,* which serves as a sensitive screen upon which images are received.

The *crystalline lens* is held in place in the front part of the eyeball by means of a ligament which surrounds it. Tiny muscles attached to this ligament can change the thickness of the lens. When we wish to read or to look at near-by objects, the muscles increase the thickness of the lens, or they make it more convex than it is when we are looking at more distant objects. Because a little muscular effort is all that is required to focus the eye upon close work or upon a distant landscape, we say that the eye is *self-focusing.*

The colored portion of the eye is the *iris,* which has a hole in its center called the *pupil.* On a bright sunshiny day, a tiny muscle reduces the size of the pupil to keep too much light from entering the eye. The pupil becomes larger at night to permit more light to enter. No doubt you have noticed that the pupil in a cat's eye is a narrow vertical slit in the daytime, and that it becomes big and round at night. Cats

and owls can see better at night than you can. The iris in your eye serves as a *diaphragm* to control the amount of light that enters the eye. The eyelids serve as a shutter to protect the eye and to keep out the light when we wish to sleep or to rest our eyes.

**254. How does the eye form images?** Suppose we have an object that is distant from the eye one foot or more. The rays of light reflected from that object enter the eye and are focused upon the retina. [See Fig. 11–8.] The image formed

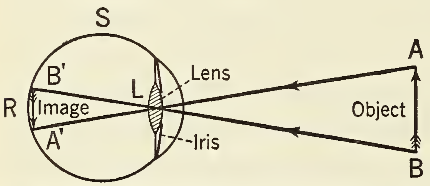



FIG. 11–8. The lens L of the eye forms an inverted image A′B′ of the object AB. The tiny image is formed on the retina of the eye.

by the lens of the eye is much smaller than the object itself. In fact, it is possible to have formed upon a tiny spot on the retina an exceedingly small but very bright image of even a 20-story building. It is upside down, also reversed, on the retina, but, through experiences gained by our other senses, the mind sees the image as if it were erect.

**255. How is the camera like the eye?** If the structure of the eye had been patented, it is doubtful whether the camera

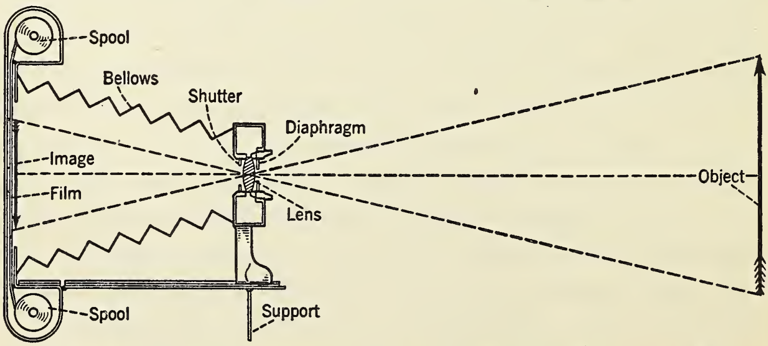



FIG. 11–9. From this diagram one can see that the camera is much like the eye in the way in which it forms images.

would have been invented. It is patterned after the eye. Let us compare the diagram of the camera, Figure 11–9, with that of the eye in Figure 11–8.

The lens of the camera is similar to the lens of the eye, and it forms the same kind of image, smaller than the object and inverted.

The *sensitive film* or the *plate* of the camera receives the image in much the same manner that the retina receives the image in the eye. The stiff walls of the camera are similar to the tough, outer coat of the eye, and the interior of the camera is painted black to absorb the stray rays of light that might fog the image.

Before one takes a picture, he regulates the size of the opening in the diaphragm of the camera. The diaphragm corresponds to the iris of the eye, and the opening in it corresponds to the pupil of the eye. On a dark, gloomy day a rather large opening is used. On an exceedingly bright day, the opening may be only a trifle larger than a pinhole.

The *shutter* of the camera corresponds to the eyelids of the eye. Do you not agree that the camera would infringe upon the rights of the eye, if the eye were a patented instrument or invention?

**256. Which is superior, the eye or the camera?** In some ways the eye is superior to the camera, and in some other ways the camera has the advantage. Let us compare the two, mentioning some advantages and some disadvantages in each case.

*a) The eye has some advantages.* The muscle that supports the lens of the eye can change the shape of the lens to make it *self-focusing*. We change the lens of the eye almost instantly from its focus upon a printed page to a distant object, or vice versa. The lens of the camera is of glass and has a fixed focus. In focusing a camera, we change the distance between the lens and the sensitive film by means of an adjustment in the box of the camera.

The pupil of the eye is also *self-regulating*. The iris ad-

justs the size of the pupil to the amount of light needed. The opening in the camera must be adjusted by the operator to meet light conditions.

Because we have two eyes, we get depth of vision or *perspective.* The camera picture is flat and has no perspective. It is possible to use two cameras bound together, make an exposure, and then mount the two resulting pictures side by side to be viewed in a stereoscope if one wishes to get depth of vision.

The eye sees objects in their true color, and most films show only lights and shadows. However, it is possible to use film that will give pictures in color.

*b) The camera has some advantages.* The camera is not partial. It records all the objects on the landscape with no bias at all. The eye misses many details. The mind of the observer picks out some parts of the image, remembers them distinctly, and forgets certain details. For that reason, a photograph may be more valuable in a trial in court than the testimony of an eye-witness. For the study of astronomy, photographs are very important.

The still camera takes a picture of a scene as it appears at that instant. The eye forms a series of images of the scene. The mind may then blend several different images to make a composite picture.

A number of years ago the judges in the Olympic games awarded a runner fifth place in the close finish of the 100-meter dash. The motion pictures of the blanket-finish showed clearly that that runner was second. Motion pictures taken during a football game show more clearly what each man is doing than do the eyes of any coach. When the pictures are shown, and the coach tells a player where he should have been "on that play," there is no argument.

257. The simple magnifier. If we hold a double convex lens fairly close to one eye and then look through the lens at some object on its opposite side, we find that the object seems larger than it actually is. Such lenses, which are called *simple*

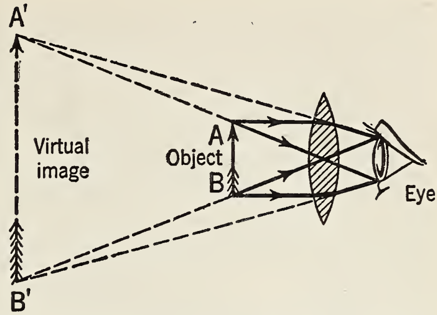



FIG. 11–10. A double convex lens may be used as a magnifier. To the eye, the object AB appears as represented at A′B′, magnified several times.

*magnifiers,* may increase the apparent size of an object by several diameters. [See Fig. 11–10.]

**258. Of what does the compound microscope consist?** If we look at the diagram of the compound microscope, shown in Figure 11–11, we see that it has two lenses or two sets of lenses, mounted in opposite ends of a tube several inches in length.

The object to be examined is placed on a glass slide which is then laid upon the stage of the microscope. One lens, which

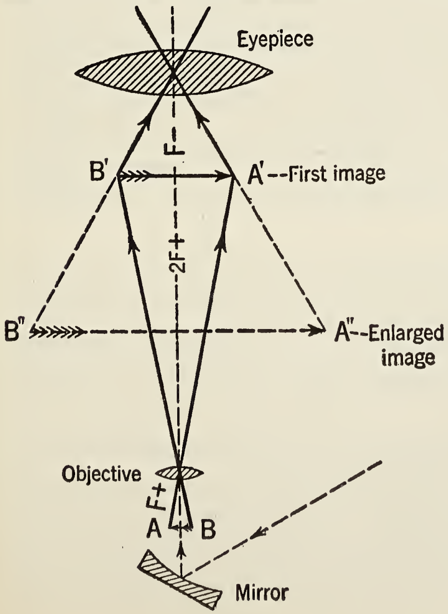



FIG. 11–11. In the compound microscope an objective lens is used to magnify the object and form an enlarged image. That image is then magnified again by the use of the eyepiece, which acts as a simple magnifier.

is called the *objective,* is then moved until it is very close to the object to be magnified. The objective lens is mounted at the lower end of the metal tube, which can be lowered or raised at will by means of a thumb screw. A concave mirror is mounted below the stage. It is designed to collect a large number of light rays and focus them upon the object to be magnified. *The objective lens forms inside of the tube an enlarged, inverted image of the object.*

Another convex lens, called the *eyepiece,* is mounted in the opposite end of the brass tube. It is focused on the image which is formed by the objective lens. The eyepiece is just like a simple magnifier, and it *magnifies the magnified image* which was formed by the objective. Now it is easy to understand why this optical instrument is called a *compound* microscope.

If the objective lens magnifies the object by eighty times and the eyepiece then magnifies the enlarged image by 10 diameters, then the object which is being magnified will appear to be 800 ($80 \times 10$) times as wide and long as it actually is. Since it is magnified in *all* directions, it will appear to have been multiplied in size or bigness 640,000 ($800 \times 800$) times.

If you are interested in learning something of some of the marvelous things that have been done and are being done as a result of the invention of the compound microscope, you will do well to read the book called *Microbe Hunters,* by Paul de Kruif.

**259. Of what does the telescope consist?** In our study of the stars, we referred to the astronomical telescopes and the purposes for which they are used. The *terrestrial telescope* is used by landsmen, sailors, army officers, surveyors, and even for sighting rifles.

In its construction, a refracting telescope is somewhat like the microscope. It has an objective and an eyepiece mounted at opposite ends of a metal tube. In the microscope the objective is a *tiny lens* which is placed *near* the object and it forms an *enlarged* image of the object. In the largest tele-

FIG. 11–12. With the aid of a telescope, you may find many of the interesting planets and constellations. If you can obtain a telescope, see how many you can find and recognize. (*The American Institute*)

scopes the objective may be as large as 40 inches in diameter and it may weigh about one ton. It forms a tiny image which is exceedingly bright. The tube of the microscope is a few inches in length, but the tube of the refracting telescope may be more than 60 feet long. The huge tube is so mounted that it is controlled by clockwork, which moves the telescope to focus it upon any particular star or planet. [See Fig. 11–12.]

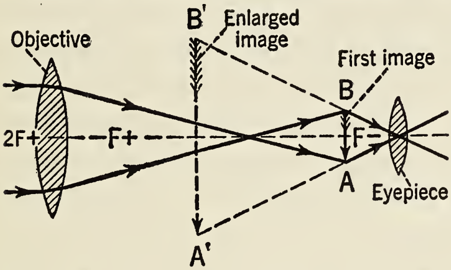



FIG. 11–13. The telescope uses an objective to form a small, very bright image. That image is then magnified by the eyepiece.

From a study of Figure 11–13 we see that the objective lens of the telescope forms a small, inverted image which is highly magnified by the eyepiece. Some telescopes magnify as much as 3000 times.

**260. How can one project pictures on a screen?** If we wish to project pictures on a screen, we use a rather large double-convex lens. The picture to be enlarged is placed in a slide holder which is fairly close to the lens and in front of it. The screen is usually 20 feet or more distant. Since

the image formed is much larger than the object, it will be very faint because it is spread out over a very large area on the screen. For example, a three-inch lantern slide may appear on the screen to be nine feet wide. In order to have a bright image appear on the screen, it is necessary to concentrate upon the lantern slide picture a great deal of light. Let us refer to Figure 11–14 to see how this is accomplished.

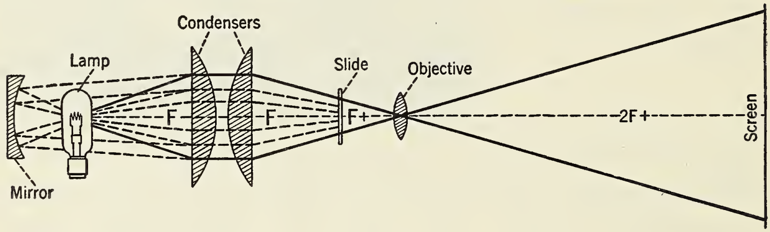



FIG. 11–14. A double convex lens may be used to throw an enlarged image upon a screen.

A powerful lamp of from 200 watts to 1000 watts is used to illuminate the slide. A reflector is placed behind the lamp to increase the illumination of the slide. Then two large lenses, from 4 inches to 6 inches in diameter, are used to gather the *divergent* rays of light and concentrate them upon the slide, too. Such lenses are called *condensers.* The same principles are used, whether one wishes to show still or moving pictures.

**261. How do we see motion pictures?** If you rotate rapidly a wheel that has spokes, you do not see the individual spokes. To your eye the wheel appears solid. It has been proved that our eye continues to see an object for about *one-sixteenth of a second* after the object has been removed. It takes about that length of time for the image formed on the retina of the eye to fade out or disappear. This phenomenon is called the *duration of vision* or the *persistence of vision.* Now we can understand why the wheel appears solid. We see one single spoke, but before the image of that spoke has faded from the retina, another spoke comes into view. If you look at one picture upon a screen, and then another comes

into view before the image of the first one has disappeared, you get the effect of seeing continuous moving pictures.

The operator of a motion-picture camera makes from 20 to 50 exposures of a moving object per second. As the film is exposed, it is being unwound from one roll and being wound on another. Then the film is developed and fixed so that it will be ready for showing.

The lamp, the condensers, and the projecting lens used in the motion-picture machine throw images of the film pictures on a screen in exactly the same manner that the pictures of a lantern slide are thrown upon a screen. There must be a small electric motor, however, to keep the film moving, rolling it up on one spool as it is unrolled from another. If we really look at the pictures while they are moving, they will appear blurred and streaked. Each picture of the film must come to a complete stop and remain stationary while we are looking at it. A shutter is opened so we can see the picture while it is standing still and the shutter then closes while the film moves on. It opens again to give us a glimpse of the next picture. Thus we get a glimpse of one picture, and then of another one before the image of the first one has faded from the retina of the eye. The pictures are shown at about the same rate that they were exposed when the pictures were taken. The human mind interprets these closely related, successive pictures as expressing continuous motion.

## *Questions*

1. Show by a diagram how it is possible to arrange two mirrors so that a person on the north side of a building can see someone on the south side of the building.
2. Is it possible so to place a large mirror by the roadside that an automobile driver can see a car coming around a "blind curve"? If so, why do you suspect they are not in common use?
3. Under what conditions does light travel in a straight line?
4. What is meant by the refraction of light?

5. Why does it require so much practice for a man to spear fish?

6. Try to find out whether one sees a fish in its true position if his eye is directly above the fish.

7. Ask your instructor to fill a tall glass cylinder, about one foot in height, with clear water. As you stand looking down into the water in the cylinder, place one finger on the outside of the cylinder at the spot where the bottom appears to be. What do you find?

8. From your experiment of No. 7, explain why the water in the gutter may look shallow and yet come up over your rubbers when you step into it.

9. Is the water in a swimming pool deeper or shallower than it seems as you look down into it?

10. For what different purposes are lenses used?

11. What advantages has the eye over the camera as an optical instrument? The camera over the eye?

12. No doubt you have seen a motion picture in which the wheels of an automobile may at one time appear to be turning backward, at another time not to be turning at all, and at still another time to be turning forward. Can you explain how each of these effects is possible?

13. You have probably heard someone remark: "You can't fool me. I saw it." Do you agree that it is impossible to fool the eye? Is it not done every time you look at motion pictures which are really at rest when you see them? Before you give your answer, think of some sleight-of-hand entertainer you have seen.

14. The fact that we still continue to see an object for a fraction of a second after it has been removed is called "duration of vision." Do you think from any experience that you have ever had that there is such a thing as "duration of sound"?

## *Some things for you to do*

1. Repeat the cup and penny experiment described in section 249.

2. Make a simple periscope by the use of two small plane mirrors set at angles of 45° at each end of a tube a couple of feet long. The tube may be made of thin pieces of wood.

# *We Increase Our Force or Our Speed by Using Machines*

THE automobile is a large complex machine. As one looks at it or rides in it, he may wonder how anyone was ever ingenious enough to make such a machine. Possibly you have wondered whether you will ever understand how it operates, what makes it go, or for what purposes all of its parts are used. If you try to study it as a whole, you will probably not be very successful. If you study the different parts, you will soon begin to realize that the automobile is made up of the various simple machines which we shall study in this unit. You will find gear wheels used to vary speed, just as they control the speed of the hands of a clock. You will find that the clutch pedal, the brake pedal, and the ignition key are levers that follow the same mechanical principles that you find in a crowbar, a can opener, or a seesaw. You will find that the rear wheels and the steering wheel are examples of the wheel-and-axle machine.

Some simple machines are used by man to multiply his own rather feeble efforts. The lever, the block and tackle, and the jackscrew are examples. The same machines and also many others may be used to multiply speed. The bicycle is a common example. But it is impossible for man to make any machine which will multiply *both* his speed and his efforts at the same time. When man gains force by using a machine, he sacrifices speed. If he gains speed by the use of a machine, he does so by sacrificing force. If he could gain both force and speed at the same time, he would be creating energy. No machine can create energy. It is impossible to get more work out of a machine than the equivalent in energy one puts into that machine. With the exceptions of fresh air and sunlight, one can find few valuable things in nature without paying an equivalent price to make them useful or available.

## *THINK ABOUT THESE!*

1. Do you think that any machine can be used to create energy?
2. For what purposes does man use machines?
3. Do you think that the bones in your forearm really act as a machine?

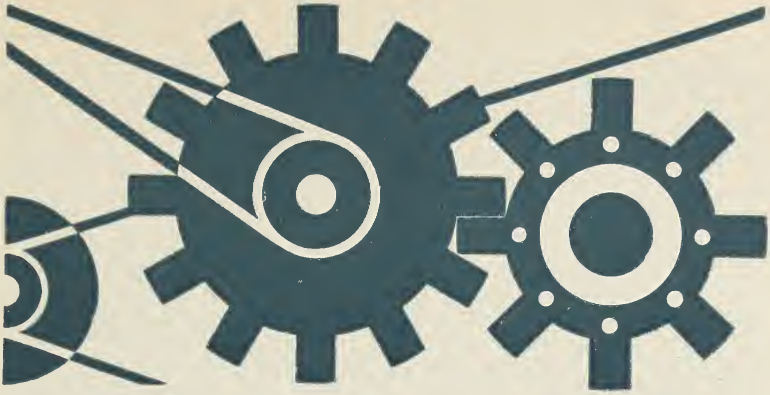
## *WORDS FOR THIS CHAPTER*

**Equivalent.** Of equal value; capable of producing the same effect.

**Fulcrum.** The support about which a lever moves.

**Ramp.** An inclined plane, or slope.

**Efficiency.** The useful work done by a machine compared to the total work put into the machine.



CHAPTER 12 ——— UNIT 6

# Why Has Man Learned to Use Machines?

**262. Why does man use machines?** In his use of machines, man is interested in two different types: machines which *transform energy* of one kind into energy of another kind; and machines which *transfer energy* from one place to another.

*a*) *Machines which transform energy.* You start a gas engine. You are transforming the energy of the exploding gasoline into mechanical (moving) energy in the engine that drives your car. You turn on an electrical switch. You may be changing electrical energy into heat energy in a bread toaster, electrical energy into light energy in an incandescent lamp, or electrical energy into the mechanical energy which runs an electric fan, a refrigerator, or a washing machine. The coal fed into a fire box produces steam. The heat energy of the burning coal is transformed into mechanical energy in the running of a locomotive. [See Fig. 12–1.]

At Niagara Falls, for example, water flows down through water wheels. Its energy is transformed, or converted, into

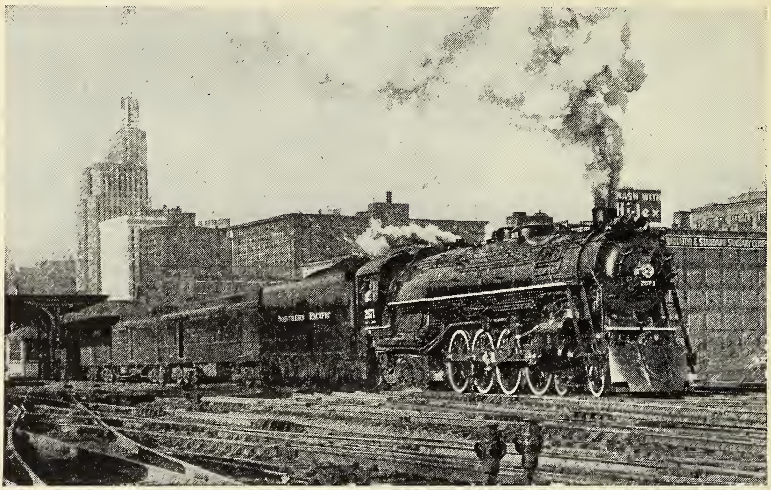



FIG. 12–1. The energy from burning coal is used to produce steam, which in turn can expand and drive the pistons which turn the drive wheels of a locomotive. (*Courtesy Northern Pacific Railroad*)

electrical energy. Such changes of one kind of energy into another are taking place all around us at almost all times.

*b*) *Machines which transfer energy.* You have seen men put up a *block* and *tackle,* or a system of fixed and movable *pulleys,* in order to hoist a piano up to the second floor of a building. Why do they go to so much trouble? Would it not be quicker to have one man carry it upstairs? It would, if the man were strong enough. A man uses the block and tackle as a machine to *multiply his force or his effort.* [See Fig. 12–2.] In a similar manner, a barrel weighing 300 pounds is to be loaded into a motor truck. A man, not being strong enough to lift the barrel, gets a long plank, rests one end of the plank on the ground and the other end on the rear of the truck, and then rolls the barrel the whole length of the plank. Thus we see that man uses a rather small effort, which moves the whole length of the plank, in order to lift a rather large weight through only a short distance.

If you wish to make a quick trip to the post office, you may hop on a bicycle and ride there quickly. Every time that


FIG. 12–2. A huge block and tackle is being used to handle this heavy pipe through which oil will be transported from Texas to Chicago. This photograph was taken near Glenwood, Iowa. (*Philip Gendreau*)

you move the pedals once around, the wheels of the bicycle move forward about 30 feet. When not much effort is needed, we may use a *machine to multiply speed.* If you had to ride up a steep hill all the way, you might not save any time by using a bicycle.

In order to raise a flag to the top of a tall flag pole, a pulley is attached to the top of the pole. A rope is then run through the pulley at the top. The length of the rope must be twice the height of the pole. If one end of the rope is fastened to the flag, and you pull upon the other end, the flag is lifted to the top. For every pound the flag weighs, you must pull on the rope with a force of a pound. *There is no advantage of force.* For every foot you shorten the rope, the flag rises only one foot. *There is no advantage of speed.* What do you gain? You do not have to climb the pole and carry the flag up with you. The simple pulley used as a machine is for convenience. *It merely changes the direction in which the force acts.*

It would be hard for a farmer to get his horses up into a hay mow to pull the hay up into the mow. It is easy for him to use a couple of pulleys fastened so that the horses may walk along the ground and pull the hay up into the mow by means of a rope and some pulleys.

To summarize, man uses machines *to multiply force* or *to multiply speed* and *to change the direction of the force.*

**263. What two forces must we consider?** In the use of a machine, there will always be at least two forces to be considered.

*a*) *The acting force.* This force represents the effort that must be applied to the machine to operate it. We shall call it *effort,* or *acting force.* It may be defined as muscular exertion, or its *equivalent,* which is used upon the machine in order to overcome some resistance.

*b*) *The resisting force.* This is the force to be overcome, or to be moved by the machine. Friction may be a part of that force. The weights of the parts of the machine itself may also form a part of such force. And, most important of

all, the weight or object to be moved by the machine is also a part of the force, which we shall call the *resistance,* or the *resisting force.* Let us use the lever to illustrate.

**264. What do we mean by mechanical advantage?** Suppose we use the following experiment to show an advantage gained by a machine. You take a firm grip on a meter stick, holding it in the middle. Another pupil presses down upon one end of the meter stick with his little finger. Can you keep him from turning the stick? Probably not. Does that mean that he has more strength in his little finger than you have in your entire hand? After thinking over the question, you may conclude that his use of the meter stick as a simple machine must give him an advantage over you.

**265. How is the lever used as a machine?** We may define the lever as a rigid, inflexible bar which is free to move about a fixed point called the *fulcrum.* In Figure 12–3, the *acting*

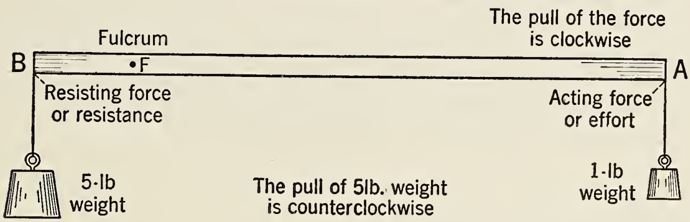



FIG. 12–3. One of the simplest and most-used machines is the lever.

*force* is usually applied at one end of the lever, and the *resisting force* is then applied at the other end. The fulcrum F lies between the two forces. We can see that the acting force is trying to turn the lever in the direction in which the hands of a clock move, and that the resisting force is really opposing such motion and attempting to turn the lever in a counterclockwise direction. If we have a ruler and a set of weights we can find out what advantage is gained by the use of the lever.

Suppose the lever is 6 feet long and the fulcrum is 1 foot from the point to which the resisting force is applied. It is

also 5 feet from the point at which the acting force is applied. If we experiment long enough, we shall find that a one-pound weight applied at A will just counterbalance the effect of a five-pound weight applied at B. By the use of such a lever, a *man can multiply his effort by five,* because every pound of effort he applies at A can counterbalance five pounds of effort applied at B. We call that a mechanical advantage of 5. The mechanical advantage of any lever always equals the length of the arm to which the effort is applied divided by the length of the arm to which the resistance is applied. A lever of this type is called a *first-class lever.* In such a lever the fulcrum is always at some point between the effort and the resistance. Can you understand now why you could not hold the meter stick and keep it from turning?

If a man sits on the short arm of such a lever, he finds that he can counterbalance a weight at the other end just equal to one-fifth of his weight. If he pulls his end of the lever downward one foot, for example, then the far end of the lever is pushed upward a distance of 5 feet. It moves five times as fast and five times as far. Hence by using the lever in this way, *one gains speed.* [See Fig. 12–4.]

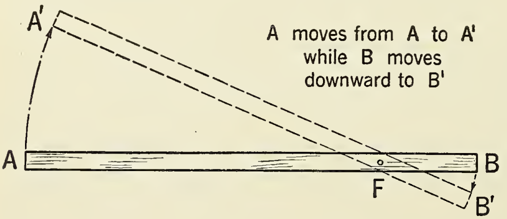
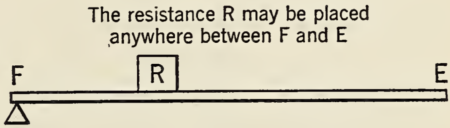



Fig. 12–4. A lever may be used to multiply either force or speed, but not both at the same time.

If the long arm of a lever is 10 times as long as the short arm, that lever can be used to multiply the acting force by 10. It was Archimedes, a Greek mathematician, who worked out the principle of the lever. He is said to have made the remark that he could lift the earth with a lever long enough, provided he had some place to put the fulcrum.

266. What other types of levers have we? Of course it is possible to have the fulcrum at one end of the lever. Then it is possible to apply the acting force at the opposite end and have the resisting force applied between the acting force and the fulcrum. [See Fig. 12–5.] The arm, EF, must always be

Fig. 12–5. A lever of this type is always used to multiply force or effort.




longer than the arm *RF*. It follows, then, that such a lever is always used to multiply force, and that it can never be used to multiply speed. A lever of this type is called a *second-class lever.*

It is possible, too, to have a lever so arranged that the fulcrum is at one end, the resistance is at the opposite end, and the acting force is between the two. The arm on which the resistance acts is longer than the arm upon which the effort acts. Hence such a lever can never be used to multiply force. It is always used when we wish to multiply speed. Figure

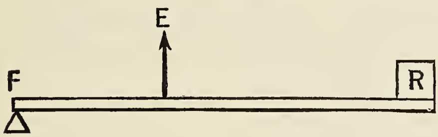



Fig. 12–6. The third-class lever is always used to multiply speed.

12–6 shows the arrangement needed for a lever of this type, which is called a *third-class lever.*

In a lever or in any other machine, we shall find that *it is impossible to gain both force and speed at the same time.* When a man uses a machine to multiply force, he sacrifices speed. If he multiplies speed he sacrifices force.

267. Where does one find levers in use in or about the home? Try to open a heavy door by pushing it: (*a*) near the edge farthest from the hinges; (*b*) in the center of the door; and (*c*) near the hinges. How is the ease of opening the

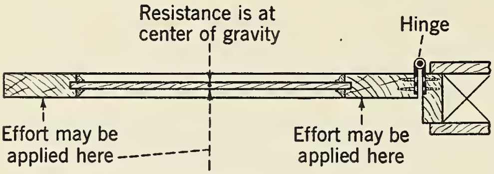
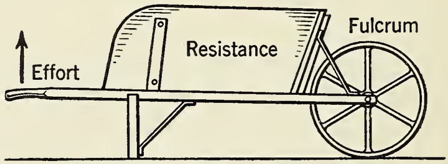



Fig. 12–7. The door is really an example of a lever, with the hinges acting as fulcrum.

door affected as you shorten that part of the door width upon which you are pushing? How is the speed of opening the door affected? Can you show how your experiment uses the door to illustrate two types of levers? [See Fig. 12–7.]

Look at Figure 12–8. Where do you find the fulcrum when you use the wheelbarrow as a lever? Where is the

Fig. 12–8. The wheelbarrow is an example of a second-class lever.




effort applied? Where is the resistance? What class of lever is the wheelbarrow?

A pair of shears is a double lever. Locate the acting force, the resisting force, and the fulcrum in the use of shears. [See

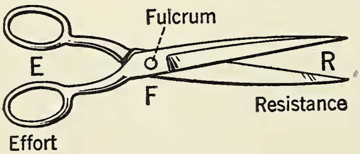



Fig. 12–9. Why does one use long-handled shears to cut tin, and long-bladed shears to cut paper?

Fig. 12–9.] The ordinary nutcracker is also an example of a double lever. Is it used to gain force or speed?

The can opener, the broom, the shovel, the spade, the claw hammer [see Fig. 12–10], the pump handle, and a pair of pliers are all examples of levers used in and around the home. The hand brake, the gear-shift lever, and the clutch

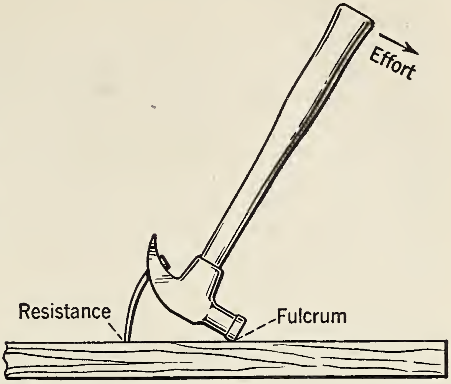



Fig. 12–10. The hammer used for drawing nails is a bent lever of the first class. The friction between the nail and the wood offers the resistance, and the effort is applied at right angles to the handle.

and brake pedals are examples of levers used in handling a car. The oar of a rowboat is a lever. The bones of your forearm act as a lever in lifting a weight upon the hand. The lower jawbone is also a lever. In all the cases mentioned in this paragraph, try to locate the position of the acting force, the fulcrum, and the resisting force. In each case, try to determine whether the lever is used to multiply force or to multiply speed. [See Fig. 12–11.]

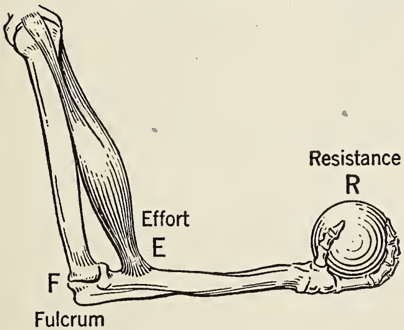



Fig. 12–11. The bones of the forearm serve as a lever. The fulcrum is at the elbow. The biceps muscle furnishes the effort. Such a lever is used to gain speed.

268. The pulley is a simple machine. In the illustration of the flag and flag pole, we learned ~~that a single fixed pulley~~ merely changes ~~direction~~. [See Fig. 12–12]. The pulley clothesline is another example, although in that case we have two fixed pulleys. If you have double-hung windows, you will find a fixed pulley mounted in the frame on either side

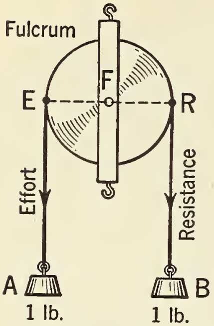
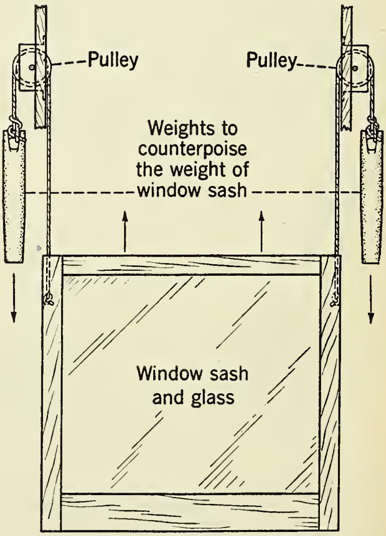



FIG. 12–12. Most pulleys have a groove in the rim of the wheel. The rope runs in such a groove. With a single fixed pulley, the effort and the resistance move in opposite directions. They both travel at the same speed. There is neither a gain in speed nor a gain in force. How many examples of such a pulley can you name?

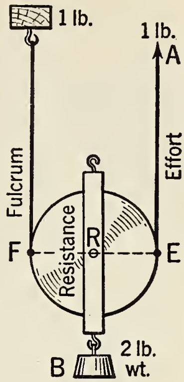
of the window. Sash weights inside the frame are fastened to one end of a cord that passes over the pulley. The other end of the cord is fastened to the edge of the window. When we try to lift the window, the sash weights aid us. They move downward inside the frame as the lower window sash moves upward. [See Fig. 12–13.]

FIG. 12–13. If you watch a carpenter setting a double-hung window, you will see him weigh the window sash and glass. Then he will use for the lower sash two weights whose combined weight is a trifle less than that of the sash and glass. Should the weights for the upper sash weigh somewhat more or somewhat less than the sash and the glass?




It is possible to fasten one end of a rope to a hook, pass the rope through a *movable pulley,* attach the resistance or weight to the frame of the movable pulley, and then apply the acting force to the free end of the rope. [See Fig. 12–14.] In such

FIG. 12–14. In the diagram for the single fixed pulley, you will notice that the pulley may be attached to a support by means of a hook. In the single movable pulley, you will notice that the resistance to be moved is attached directly to the pulley block and that both of them move together in the same direction. The effort is only half as great as the resistance, but it must move twice as far. At the sacrifice of speed, one gains force.




a case, we have a mechanical advantage of *two,* since the hook is actually supporting one-half of the resistance. One pound of effort applied at A will support 2 pounds of resistance at B.

With a *block and tackle,* arranged as shown in Figure 12–2, we have a combination of fixed and movable pulleys.

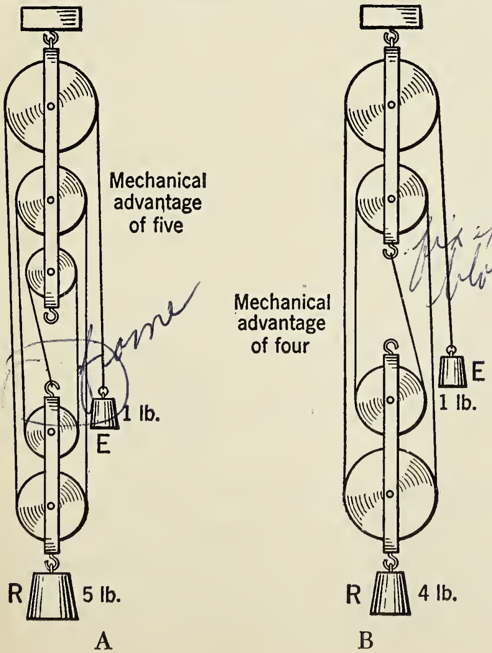



FIG. 12–15. Many different combinations of fixed and movable pulleys may be used. The effort may be arranged for a downward pull, for an upward pull, or for a pull in any other direction. A combination of pulleys is known as a block and tackle.

The resistance is attached to the frame of the movable pulley block. One end of the rope may be attached to the frame of the movable block, as shown in Figure 12–15A, or to the fixed block, as shown in Figure 12–15B. The effort is applied at the free end of the continuous rope or cord. The mechanical advantage of force of such a combination of fixed and movable pulleys is equal to the number of divisions of rope that support the movable block. In the arrangement of Figure 12–15A it is five, and in the arrangement of Figure 12–15B it is four.

Moving vans carry a block and tackle for hoisting heavy pieces of furniture. Farmers use such apparatus for unloading hay and carrying it up into the hay mow. The block and tackle is a part of the painter's equipment. A painter uses a set of fixed and movable pulleys at each end of his ladders when he uses them as a painter's scaffold. Examine the builder's crane, a steam or electric shovel, and an automobile wrecker to see whether you can find other uses of pulleys.

**269. What is that machine which is called the wheel and axle?** Did you ever try to open a door and find that the door knob was missing? If so, you found it difficult, or perhaps impossible, to turn with your fingers the square shaft to which the door knob is normally attached. The spring in the lock may have been rather stiff, and you needed a simple machine to multiply your effort. The force you use is multiplied with a machine of this type, which is called a *wheel and axle.* The advantage gained equals the diameter of the knob divided by the diameter of the axle to which the knob is attached. If the knob has a diameter of 2 inches, for example, and the axle has a diameter of one-half an inch, then the advantage is four ($2 \div 0.5 = 4$).

The front wheel of your bicycle turns on an axle. That is *not* an example of the wheel-and-axle machine. In such a machine, both the wheel and the axle are either made of one piece, or they are bolted together. The acting force is applied to the rim or circumference of the wheel, and the re-

sisting force is applied to the circumference of the axle, if we wish to have an advantage of force.

In the rear wheel of your bicycle you have a wheel and axle which you use to gain an advantage of speed. The acting force is applied through the chain to the *sprocket wheel* which is fastened firmly to the rear wheel. The resisting force is applied at the point where the tire of the wheel makes contact with the pavement. [See Fig. 12–16.]

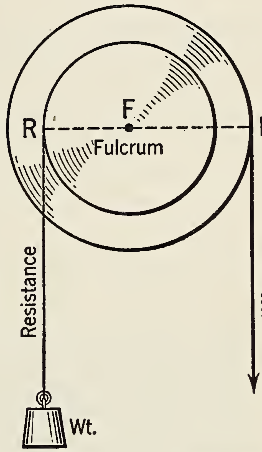



FIG. 12–16. The front wheel of an automobile turns on an axle. It must be greased to reduce friction. The rear wheel of an automobile is fastened to its axle and turns with it. Does it ever need greasing? When the rear axle turns, the rear wheel turns with it and drives the car. The wheel and axle is a simple machine which may be used to multiply speed or it may be used to gain force.

**270. What are some common examples of the wheel and axle?** No doubt every farmer boy has had to turn a grindstone or a corn sheller. With both machines he can tell where the acting force and the resisting force are applied, and whether speed or force is gained. The chain pump and the windmill are other examples used around the farm.

Every girl in the class has at some time had an opportunity to use a wheel and axle in the form of a coffee grinder, an egg beater, a clothes wringer, or a meat grinder. In nearly all these machines we find that a crank is used instead of a wheel, but the effort applied to the end of the crank describes a circumference as it moves around in a circle.

In any carpenter's tool chest we find examples of this simple machine in the brace and bit, the drill, and the screwdriver.

There are many other examples, too, of this type of machine – the fishing reel, the steering wheel of a boat, and the steering wheel of the automobile. In fact, the automobile furnishes other examples of the wheel and axle in the rear wheels which drive the car, in the crank for starting the car, in the brake drums applied to the wheels, in the door handles, and even in the lock and key.

**271. The inclined plane is a simple machine.** We are almost certain that the Egyptians who built the Pyramids did not have so many machines as we have. No one knows how they lifted the huge blocks of stone when building the Great Pyramid. It is generally believed that they pushed them up huge inclined planes. You know that it takes less force to roll a barrel up an inclined plank than it does to lift the barrel. It would be shorter to go straight up the side of a hill or mountain, if that were possible, but one finds it easier to travel a longer distance along a slanting road which winds its way to the top. To reach our seats in a football stadium, we walk along an inclined *ramp* or gently sloping passageway. The gentler the slope, the easier it is for us to walk along.

It can be shown by experiment that one has an advantage of 9 if he uses a plank 18 feet long, and one end is 2 feet higher than the other. If one end of this plank is raised until it is 6 feet higher than the other end, then the advantage is only 3. In rolling an object along an inclined plane, the

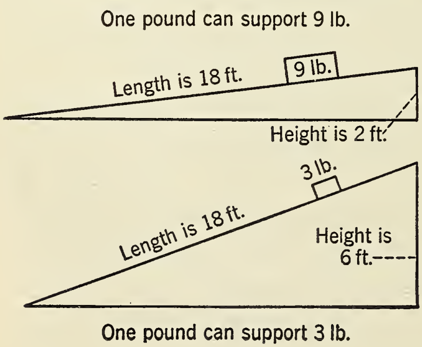



Fig. 12–17. The gentler a slope, the easier it is to walk up that slope. It takes more force to push an object up a steep slope than it does to push the same object up a more gentle slope.

mechanical advantage of force always equals the length of the plane divided by the height of the plane. [See Fig. 12–17.]

Mountain roads wind around and around the mountain in a gentle spiral so that the ascent to the top is made in easy grades. To reach the top of Pikes Peak, the road winds around the mountain for a distance of more than twenty miles, but the mountain is only 14,108 feet high, or less than three miles high. [See Fig. 12–18.]

**272. How is the wedge used as a machine?** The wedge is not unlike the inclined plane. In fact, we may consider it a double inclined plane. It is sometimes used for splitting posts and rails. There is no doubt that Abraham Lincoln knew how to use an iron wedge to good advantage, because he was nicknamed The Rail Splitter.

Such edged tools as knives, chisels, axes, plane bits, and hatchets are examples, and so are pins, needles, and nails.

Fig. 12–18. Have you ever ridden in a car over a mountain road? Can you understand why it is so costly to build such roads? In many cases they are toll roads. (*Courtesy U. S. Bureau of Public Roads*)

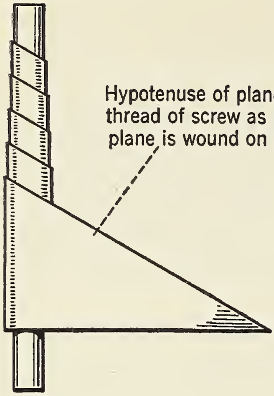
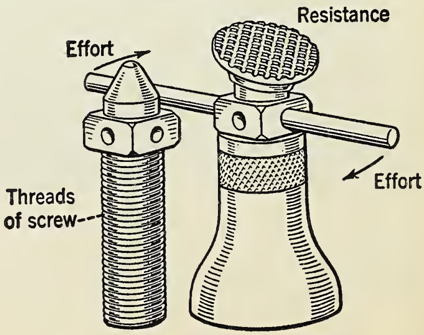



Fig. 12–19. Cut a sheet of paper to make a right triangle in which the base of the triangle is about twice as long as its height. Wind the paper around a lead pencil as shown in this figure. Does the spiral edge resemble the spiral thread of a screw? (The hypotenuse is that slanting edge of a right triangle which is opposite the 90° angle.)

273. **The screw is a simple machine.** If we take the slanting edge of an inclined plane and wind it on a cylinder, we have the spiral threads of the screw. [See Fig. 12–19.] The nuts, screws, and bolts that one finds everywhere are all examples of this machine. The plumber cuts threads on a pipe so that he can make connections which are gastight or watertight.

The jackscrew which is used for lifting buildings or automobiles is a common example of the screw. The acting force is multiplied tremendously by the use of the screw, sometimes as much as several hundred times. It is not uncommon for a force of one pound to lift 400 pounds or more. [See Fig. 12–20.] When you use a wrench to tighten a nut, you are

Fig. 12–20. The jackscrew has numerous uses. One may use such a screw to jack up a car, or to lift one corner of a building.



using the screw as a simple machine. Can you find twenty applications of the screw in the room in which you are sitting?

274. **Can we have a machine made up of two or more simple machines?** Let us examine a meat chopper. The knives that do the cutting are wedges. A spiral central cylinder acts as a screw in feeding the meat to the knives. The crank and the axle to which it is attached form a wheel and axle. The brace and bit combines both the wheel and axle and the screw. The faucet may be an example of a screw controlled by a wheel and axle.

In the shop, you may use one wheel to turn a lathe wheel by means of a belt. That is a kind of a *modified* wheel and axle, with the wheel on one shaft and the axle on another. A chain is often used when we wish to have one wheel drive another one. Two wheels may be geared together as shown in Figure 12–21. Suppose you make a rather careful study of

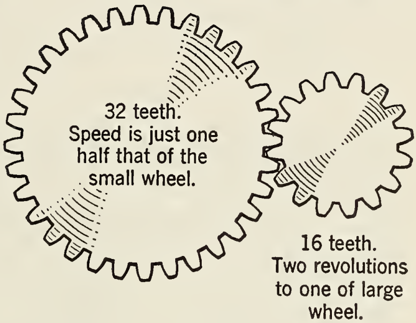



FIG. 12–21. Gear wheels are used to vary speed. Effort may be applied to one wheel and the resistance to another. In this figure the small wheel makes two revolutions for one revolution of the large wheel.

your bicycle. Possibly the large sprocket wheel to which the pedals are attached has twenty-eight sprockets, or teeth, and the small sprocket wheel, which is attached to the rear wheel of the bicycle, has only seven teeth. Then the rear wheel will turn *four times around* while the pedals are turning once around. Can you understand now why a bicycle is used to gain speed? Figure 12–22 shows how a block and tackle can be used with an inclined plane as a combination of two simple machines.

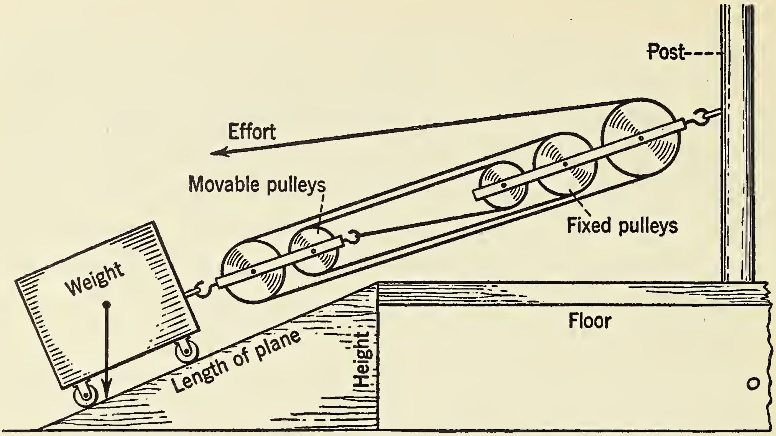



FIG. 12–22. It is not uncommon to have one simple machine act upon another machine to form a compound machine.

**275. What is meant by the term "work"?** In many cases we have had occasion to use the word *force.* We know, too, that we measure force in *pounds.* In science, however, we use the term *work* in a different sense from that to which you may have become accustomed. Possibly you think of *work* as anything that makes you tired. As scientists use the term *work,* it means *overcoming resistance* and it is measured by multiplying *force by the distance the force acts.* If a force of 40 pounds acts through a distance of 10 feet, we say the amount of work done is 400 *foot-pounds.* The foot-

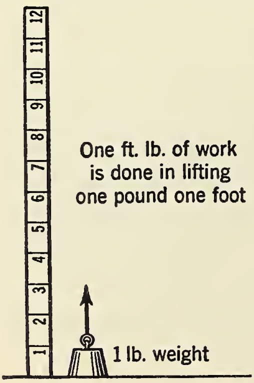



FIG. 12–23. If a man uses effort and does not accomplish any results, he may grow tired without doing any real work. If he lifts a weight of one pound through a vertical height of one foot, he is doing one foot-pound of work. If you take a job, should you be paid for your effort or for the work you do?

pound is the unit used for measuring work. *One foot-pound is the amount of work done by a force of one pound acting through a distance of one foot.* [See Fig. 12–23.] If you weigh 100 pounds, how much work do you do in climbing a flight of stairs 20 feet high? Of course you have to use a force of 100 pounds to lift a weight of 100 pounds.

If you tug on a root, and do not move it, you are not doing any work. If you hold a weight of 5 pounds on your head all day and do not move the weight, you are not doing any work.

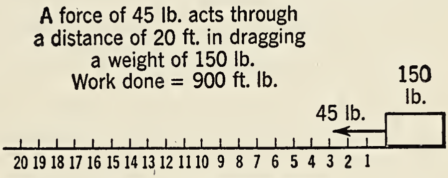



FIG. 12–24. It takes less force to slide an object than it does to lift that object against the force of gravity.

If you have to pull with a force of 60 pounds to drag a trunk which weighs 150 pounds, and you drag the trunk 50 feet, you accomplish 3000 (60 × 50) foot-pounds of work. [See Fig. 12–24.] The huge ore unloader of Figure 12–25 can work rapidly.

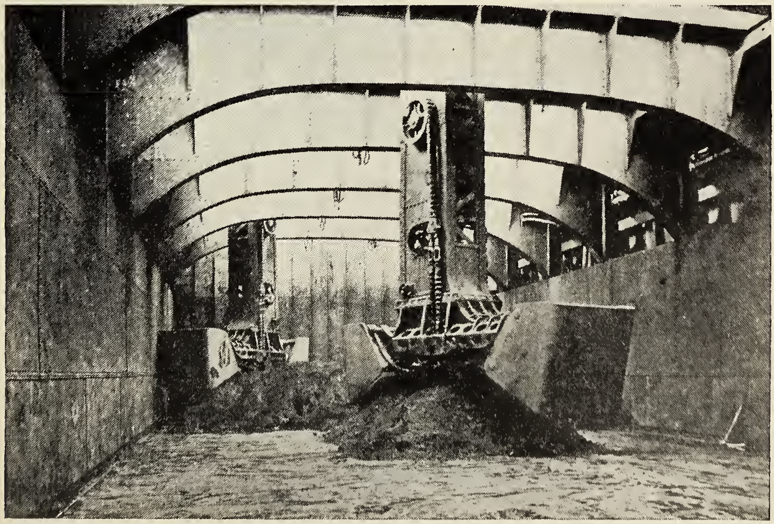


FIG. 12–25. This ore unloader works with enormous speed. (*Courtesy The Wellman Engineering Co.*)

**276. What do we mean by the term "power"?** The scientist uses the term *power*, too, in a different sense from the one to which you have been accustomed. By *power* he means *the rate of doing work.* He considers three things: (*a*) the force; (*b*) the distance the force acts; (*c*) the time, usually in seconds. When you speak of a man as being *powerful,* you generally mean that he has great strength; but scientists consider the time involved in doing work.

You use the same amount of *force* when you walk up a flight of stairs that you do when you run up the stairs. You do the same amount of *work* when you walk up a flight of stairs that you do when you run up the stairs. But it takes *more power* for you to run up the stairs than it does to walk up, because you are doing *more foot-pounds of work per second.*

In the English system of measurement, the unit used to measure power is the *horsepower* (H. P.). It is equal to 550 foot-pounds of work per second. [See Fig. 12–26.] It is

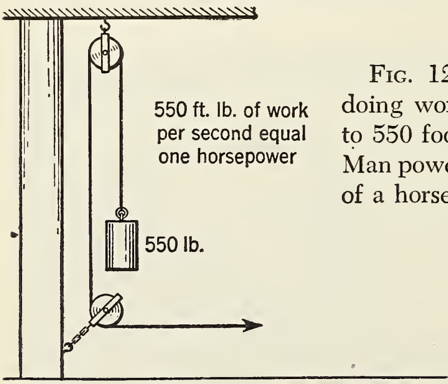



FIG. 12–26. Power is the rate of doing work. The horsepower is equal to 550 foot-pounds of work per second. Man power is not more than one-seventh of a horsepower.

called the horsepower because James Watt, during a series of experiments, found that an English dray horse could continue to do work at that rate for some length of time. For example, the horse could walk along and pull upward by means of a pulley a weight of 110 pounds at the rate of five feet per second. Steam engines and automobile engines are

rated in horsepower. A 100 H. P. automobile engine can work at the rate of $100 \times 550$ foot-pounds per second.

In the metric system of measurement, the *watt* (named for James Watt) is the unit used for measuring power. Because the watt is a rather small unit, the *kilowatt,* which equals 1000 watts, is more often used. *One horsepower equals almost three-fourths of a kilowatt.*

**277. What is friction?** If we try to slide an object over a table, we always meet with some resistance. The particles of the object and of the surface over which we are pulling it seem to lock and try to hinder motion. *The resistance which, by contact, opposes any force which is trying to produce motion is called friction.* Of course friction results in wasted work, because it increases the force that is required to move the body. We may find, for example, that a force of 40 pounds would be required to roll a weight of 160 pounds up an inclined plane if we could eliminate friction. Possibly when we try to roll the barrel up that plane, we find that it takes a force of 50 pounds. The additional 10 pounds was spent in overcoming friction.

**278. If friction is useful, we try to increase it.** You have seen a team of horses trying to start a heavy load when the street was slippery. If they succeeded at all, it was with great difficulty, because they could not get a firm foothold. Sand or ashes sprinkled on the streets will increase the friction and permit the horses to get a foothold.

When the streets are icy, the rear wheels of an automobile may spin around and around when the driver starts the car. But the car does not move forward. More friction is needed. What can we do? We may sprinkle sand or ashes over the ice to increase the friction. We may put chains on the car wheels to increase friction. In case of an emergency, we may even let a little air out of the tires, because a somewhat flattened tire grips better than one tightly inflated.

Friction material is used to line the brake bands so that they will grip the brake drums and enable a driver to stop

an automobile fairly quickly. It is not a good idea to have the rim of the steering wheel too highly polished. Why not? Why is it difficult to turn a door knob when your hands are wet and soapy?

Possibly you have vacuum-cup soles on the shoes you wear when playing basketball. Football players often wear mud cleats. Baseball players, golfers, and track athletes wear spikes to prevent slipping. The baseball pitcher dusts his fingers with rosin so that he can grip the ball firmly without letting it slip. Lumbermen leap from one log to another in the water. They are very sure-footed because their boots are studded with iron nails.

If there were no friction, do you suppose that a nail or a screw would stay in a board into which it was driven? Why do you think that the surfaces of concrete roads are left somewhat roughened instead of being troweled smooth?

**279. If friction hinders, we try to reduce it.** When we want an object to stay in place and not move, then we approve of friction. When we want something to move, such as a sled over ice, or the front wheel of a bicycle to turn on its axle, then we attempt to reduce friction. There are several ways in which friction may be reduced, of which the following are examples.

*a*) *By the use of hard, polished surfaces.* The axle on which a wheel turns is made of hard material and is highly polished. If the surface is hard, one part does not sink into the other. If it is smooth, there are no particles to interlock and tend to prevent motion. You would hardly care to dance on a floor made of rough, unplaned boards.

*b*) *By the use of balls or rollers.* Why are your feet likely to slip out from under you if you step on a marble? We put casters in the legs of a bed, a desk, a table, or a piano, because man has learned that rolling friction is less than sliding friction. We use ball bearings in our roller skates and in the wheels of our bicycle in order to reduce friction. [See Fig. 12–27.]

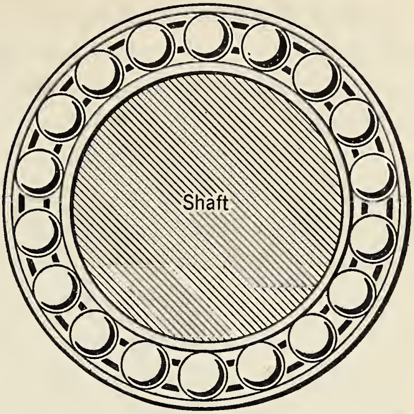



FIG. 12–27. Since rolling friction is much less than sliding friction, ball bearings or roller bearings are frequently used to reduce friction. For the same reason, we put casters on beds, desks, and other furniture.

c) *By the use of lubricants.* It is not difficult to row a small boat through the water. Suppose you try to row the same boat over the sand at the seashore. Then you will learn that *fluid friction is much less than sliding friction between solids.* When we put oil in the bearings of a machine, we make it possible to have a liquid film between the two moving parts. Then they slide over the liquid film easily. A good lubricant should have body enough so it will not run out of the bearing, or be squeezed out by the weight of the parts. It must not evaporate or become gummy. Of course it must not cause the bearing to rust.

**280. What is meant by efficiency?** No one ever gets *any more work out of a machine than he puts into it.* A machine cannot create energy. If a man could get more work out of a machine than he puts into it, then he could build a perpetual-motion machine.

It is impossible, too, for a man to get as much work out of a machine as he puts into it. If he did, that machine would be working at an *efficiency* of 100 per cent. This situation can only happen if friction is reduced to the zero mark and the weights of the parts of the machine do not hinder the operation of the machine.

If we multiply the acting force by the distance that the acting force moves in operating the machine, we get the

*input,* or the work that is put into the machine. That product gives us the *total work* that is put into the machine, and it includes both *useful work* and *the work used to overcome friction.*

If we multiply the resistance by the distance that the resistance is moved by the machine, that gives us the *output,* or the *useful work* accomplished by the machine. The *efficiency of any machine equals the output divided by the input.*

Let us take an example. A force of 50 pounds acts through a distance of 40 feet along an inclined plane as it rolls a barrel weighing 400 pounds up to a doorway 4 feet high. The output, or the useful work accomplished equals 1600 foot-pounds ($4 \times 400 = 1600$). The input, or the total work used on the inclined plane as a machine equals 2000 foot-pounds ($50 \times 40 = 2000$). When we divide 1600 by 2000, we find that the efficiency of the plane was 80 per cent.

Are you marked in school on effort or work? Let us make a check. You are given 10 problems to solve. If you solve 7 of them correctly, your grade is 70 per cent. A scientist would say that your efficiency is 70 per cent, because your effort on the other three problems represents wasted work. You may have tried hard, but you did not do any useful work unless you accomplished something.

## QUESTIONS

1. Can you give examples of at least three machines which man uses to transform energy of one kind into another kind?
2. Can you make a list of six machines which man uses to multiply force, or to gain force?
3. Can you list four machines which man uses to gain speed?
4. Why should the bar from which a lever is made be inflexible?
5. Is it necessary for a lever to be straight, or is it possible to have a bent lever?
6. In the business world, is an employee usually paid for his effort or for work accomplished? Give a reason for your answer.

7. In the use of a seesaw, a boy who weighs 80 pounds sits 6 feet from the fulcrum. In order to counterbalance him, how far must a girl who weighs 60 pounds sit from the fulcrum?

8. Does the boy or the girl of problem 7 get the longer ride? Explain.

9. The earth is supposed to weigh 6,000,000,000,000,000,000,000 tons. Do you think that Archimedes could have used a lever to lift the earth, if the fulcrum were only one foot from the earth? (If Archimedes had weighed 200 pounds, he would have needed a lever more than ten billion billion miles long. If he had traveled day and night by train at 60 miles per hour, it would have taken him more than twenty thousand billion years to get out to the farther end of the lever. This assumes that the lever has no weight.)

10. In each of the following examples of levers, tell where the effort, the resistance, and the fulcrum are: (*a*) the crowbar; (*b*) the wheelbarrow; (*c*) a pair of sugar tongs; (*d*) a pair of scissors; (*e*) the oar of a rowboat; (*f*) a shovel; (*g*) a broom; (*h*) a pitchfork; (*i*) a claw hammer for pulling nails; and (*j*) a spade.

11. Is it possible that some of the levers mentioned in question 10 can be used as two different kinds of levers? Can you show, for example, that the broom, the shovel, and the pitchfork can be so used that in one case they may be first-class levers, and used in a different manner they may be third-class levers?

12. The bones of the forearm serve as a lever upon which the biceps muscle acts. [See Fig. 12–11.] What class of lever is it? Do we gain force or speed by its use?

13. Where is the effort, the fulcrum, and the resistance when you use your foot as a lever in raising the body on tiptoe?

14. What kind of simple machine is used in cranking a car by hand?

15. What kind of machine is a hand clothes wringer?

16. What kind of machine does one use in winding a watch or a clock?

17. What kind of machine is a faucet?

18. What is the advantage in having a *large* steering wheel for an automobile?

19. A hill that rises one foot in one hundred feet of its length is said to have a 1-per-cent grade. What do you think is meant by a 10-per-cent grade?

20. Make a list of as many uses as you can for the inclined plane.

21. Make a list of as many applications of the screw as you can find around the home and the garage.

22. Which is easier for a man, to climb a 20-foot ladder with a hod of bricks weighing 50 pounds on his shoulder, or to pull the hod of bricks up to the same height by the use of a rope and a fixed pulley? Explain.

23. Do you think you would be able to walk if there were no friction?

24. Make a list of as many cases as you can where friction is useful.

25. Make a list of half a dozen cases where we try to reduce friction.

26. What methods are in common use for reducing friction?

27. A certain machine is planned so that 1 pound will lift 5 pounds. In actual use, it is found that it does lift only 4 pounds. What is its efficiency?

28. Should you be graded in school principally on your effort or on tasks accomplished?

## *Some things for you to do*

1. Make a mark on the tire of the rear wheel of a bicycle. Count the number of times the rear wheel turns for one complete revolution of the pedals. Then count the number of teeth on the sprocket wheel attached to the pedals and divide that number by the number of teeth in the sprocket wheel which is attached to the rear wheel of the bicycle. How do the two quotients compare? To find out the mechanical advantage of speed, divide the distance, measured along the pavement, that the bicycle moves forward during one complete turn of the pedals by the distance that one pedal moves during the same time.

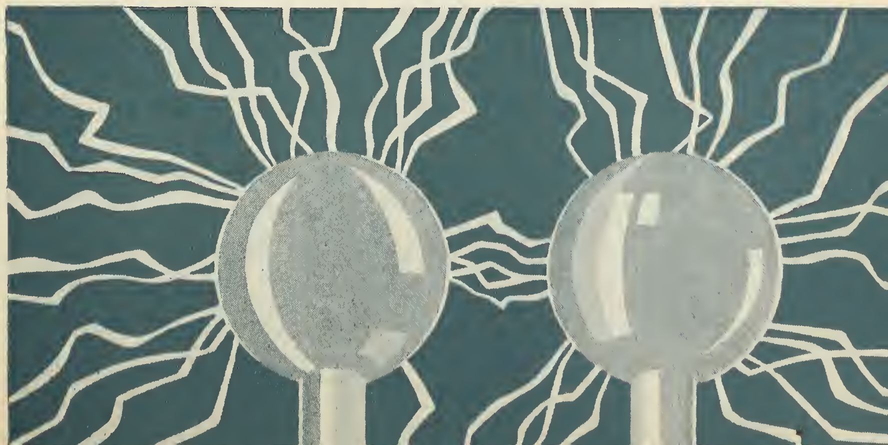
2. Make a list of all the machines you can find around the home. Put each one in the class to which it belongs, by placing it under the appropriate one of these headings: *lever, pulley, wheel and axle, inclined plane,* and *screw.*

# *We Make Use of Magnetic and Electrical Energy*

EARLY voyagers used to tell about a supposed lodestone, a great magnetic mass in the ocean, which disturbed a ship's compass and, if the ship came too near, drew out all the nails and other metal parts.

This legendary magnet was supposed to work like the ordinary magnets with which children play, but on a larger scale. The effects of any magnet, large or small, can be studied, but even after you have studied them, you will still wonder what magnetism is. No one seems able to explain why a magnet attracts iron and steel. That attraction is as much a mystery as the force of gravitation, by which an apple falls to the ground. There is always hope, however, that in the future someone may come forward to explain the until-then unexplainable.

Electricity is almost as mysterious as is magnetism. In cold, dry weather, when you touch a person's or a cat's ear, why do you sometimes bring about an electrical spark? Why



do the hairs on your head fly apart and seem to repel each other when you use a hard-rubber comb in cold weather? It is not possible to explain why electricity behaves as it does; but man has learned how it behaves.

In this unit we shall study some of the laws of magnetism and electrical energy. We shall learn how to generate electricity. And we shall study about the uses to which man has learned to put electricity. It is not incorrect to say that man has *tamed* electricity, that he has harnessed it, and that he uses it as a faithful servant to work for him.

## *THINK ABOUT THESE!*

1. Do you know of anyone who can explain why a piece of iron is attracted to a magnet?
2. Do you know why a magnet that is so suspended that it can swing freely will take a position in a north-and-south line?
3. Sometimes the more one combs his hair, the more it tends to stand up. Can you explain?
4. Do you think it was dangerous for Benjamin Franklin to try to fly a kite during a thunderstorm?

## *WORDS FOR THIS CHAPTER*

**Magnetite** (măg′nĕ·tīt). A magnetic iron ore found in nature.
**Lodestone.** A natural magnet.
**Polarity.** A state of having poles, or places at which magnetic force is concentrated.
**Pith.** The soft, spongy matter found in some stalks and young stems.
**Phenomenon** (fė·nŏm′ė·nŏn). An observable fact or event.
**Static.** Referring to an electric charge at rest.


CHAPTER 13 ——————— UNIT 7

# *What Are Magnetism and Static Electricity?*

**281. What is meant by magnetism?** There is one kind of iron ore which has the property of attracting to itself bits of iron or steel. Under some circumstances, such a piece of iron ore will repel iron and steel. Such properties are known as *magnetism.* Iron ore which has the properties of magnetism is said to have been discovered first by the Greeks in Asia Minor. Probably they are the ones who named it *magnetite.* Magnetite has also been found in northern Michigan, in the Adirondack Mountains, and in other places. If we suspend a narrow piece of magnetite by a thread, so that it is free to turn in any position, we find that it assumes a north-and-south direction. Because one end of such a piece of magnetic material points to the north, it is often called a *lodestone,* or *leading stone.*

**282. Can we make a magnet?** Let us take a rod or a bar of steel and stroke it with a piece of magnetite. A piece of a steel knitting needle will serve well for this experiment.

In stroking the knitting needle with the magnetite, we must be careful *always to begin to stroke it from the same end.* [See Fig. 13–1.] You will notice that we always bring the magnetite back through the air gap in order to start at the

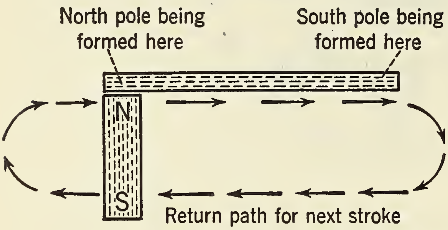
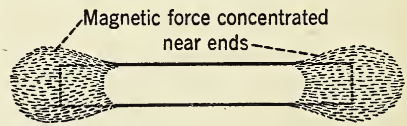



FIG. 13–1. A bar of iron may be magnetized by stroking it with a bar magnet.

same end. Within certain limits, each time we stroke the steel with the magnetite, we make it more strongly magnetic.

**283. What are the poles of a magnet?** Suppose we take the magnet that we have just made and dip it into some iron filings. We find that the filings cling firmly to the magnet at or near the ends. The two places near the ends where the magnetism seems to be greatest are called the *poles* of the magnet. From Figure 13–2 we see that there is a pole near each end of the magnet.

FIG. 13–2. Iron filings cling to a magnet near the ends of the magnet, or at the poles of the magnet.




**284. What are the laws of magnets?** Suppose we place the magnet which we have made in a small stirrup made of copper wire and suspend it by means of a silk thread. It swings to and fro for a few minutes, but it finally comes to rest with one end pointing toward the north and the other end pointing toward the south. We start it swinging again, to see whether that north-and-south position happened to have been an accident. In each trial, we find that the magnetized needle comes to rest in the same position. That end of the needle which points north we call the *north-seeking pole.* The other

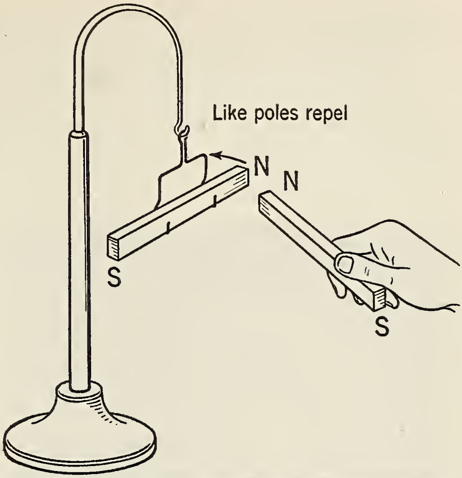



FIG. 13–3. Like poles of a magnet repel each other. Unlike poles attract each other. These statements are known as the laws of magnets.

end of the needle is called the *south-seeking pole.* [See Fig. 13–3.]

Next, when the magnet is at rest in a north-and-south line, we hold near the north-seeking pole of the suspended magnet the north-seeking pole of another magnet. We find that they repel each other strongly. If we hold the south-seeking pole of another magnet near the south-seeking pole of the suspended magnet, we find that they too repel each other. We conclude, then, from these experiments, that like poles repel each other.

We may then repeat the experiments by holding the south-seeking pole of a magnet near the north-seeking pole of the suspended magnet. We find in this case that they attract each other. We find, too, that the north-seeking pole of a magnet will attract the south-seeking pole of the suspended magnet. What do we conclude? Unlike poles attract each other. We may combine the results of all our experimental work into what is known as the *law of magnets: like poles repel; unlike poles attract.*

285. How is the magnetic compass used? Since a magnetic needle has a tendency to set itself in a north-and-south line, it can be used to locate directions. To be made into a

compass, such a needle must be mounted on a pivot so that it will be free to swing around in a horizontal direction. A disc beneath the movable needle has the points of the compass printed upon it. The north-seeking pole of a compass needle is generally marked in blue-black. [See Fig. 13–4.]

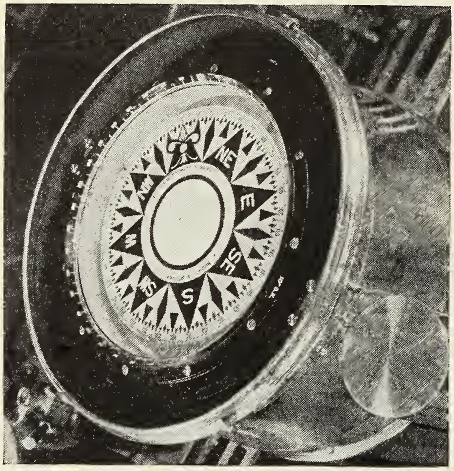


FIG. 13–4. The magnetic compass depends upon the fact that one end of the magnetic needle is attracted to the earth's North Magnetic Pole. In this mariner's compass, the points of the compass are printed on a disc attached to the compass, moving with the compass. (*Courtesy Cunard White Star, Ltd.*)

From your study of history you may remember that the mariner's compass was invented only a short time before Columbus started on his voyage of discovery. Columbus was a brave man when he set sail from Palos, in Spain, to pilot his vessels across the unknown seas. He was trusting to his compass needle to guide him across the stormy Atlantic Ocean and back home again. You may have heard, too, that his sailors threatened to mutiny and throw Columbus overboard when they got into strange waters and found that the compass needle did not always point in the direction in which they calculated that it should point. We shall learn a little later why the compass needle does not point to the true north at all places on the globe.

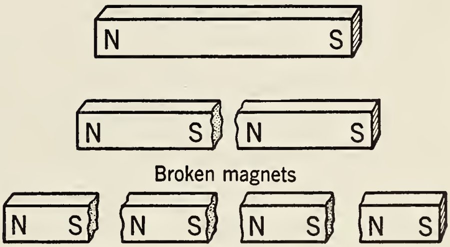
**286. What materials does a magnet attract?** It is easy to show by experiment that a magnet will attract nails, tacks, and all kinds of iron and steel objects. A magnet will also

attract small pieces made of nickel and cobalt. Substances which are attracted by a magnet are called *magnetic materials.*

Such substances as wood, copper, brass, paper, and glass are not attracted by a magnet. In fact, they do not seem to be affected in any way by a magnet. They are called *non-magnetic materials.* A few substances, such as zinc, are actually repelled by a magnet.

**287. Is it possible to remove magnetism from a magnet?** If we break a bar magnet into two pieces, we do not destroy its magnetism. Each piece will have two poles. If we break it again and again, each tiny piece will have *polarity.* Such experiments lead to the belief that each molecule of a piece of iron or steel is a tiny magnet. [See Fig. 13–5.]

FIG. 13–5. Breaking a magnet merely makes two magnets. It does not destroy its magnetism.




If we hold a magnet in an east-and-west line and tap one end of it gently with a hammer, the magnet will lose much of its strength. If we heat a magnet to a red heat, and let it cool while it is lying in an east-and-west line, we find after it cools that it has lost nearly all of its magnetism.

Soft iron is easily magnetized, and it loses its magnetism rather easily. Hard steel is difficult to magnetize, but when once magnetized it retains its magnetism very well. A magnet made out of hard steel is called a *permanent* magnet. Some alloys of nickel and cobalt make magnets that hold their magnetism particularly well.

**288. What is a magnetic field?** Let us lay a bar magnet in the hollow of a grooved board in such a manner that the

top of the magnet is flush with the top surface of the board. Then we lay a piece of paper on the board in such a manner that its center will be above the center of the magnet. Next we sift some iron filings evenly over the surface of the paper and tap the paper gently with a pencil. [See Fig. 13–6.]

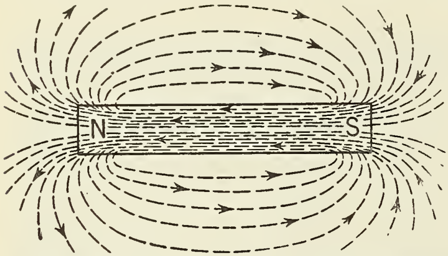



FIG. 13–6. This diagram shows how lines of force permeate the field about a magnet. They are closed curves, more closely crowded near the poles of the magnet.

The lines, which are called *lines of force*, show the position of a part of the *magnetic field* which is the area surrounding the magnet for a distance of three feet or more. A compass needle is affected by the magnet if it is brought anywhere within the field of the magnet. In a similar manner, any piece of iron that is brought into the magnetic field of a compass needle disturbs the needle. If we expect to get reliable results when we work with a magnetic needle, we must first remove all magnetic material to a distance of at least one yard. Beyond that distance the magnetism is very feeble.

*289. **What is the theory of making a magnet?** From many facts that have been learned about magnetism, it seems that each molecule of iron or steel in the magnet is a tiny magnet. When the iron or steel bar is not magnetized, the molecules are probably arranged in a miscellaneous manner. [See top part of Fig. 13–7.] As we stroke the unmagnetized bar with a magnet, we turn some of the molecules around until we have the majority of them arranged along the bar of iron with their north poles pointing toward one end, as shown in the figure. If we continue to stroke the iron bar, we reach a point where all the molecules are turned with their north pole toward one end, as shown in the lower part of Figure 13–7. The iron bar is then saturated with magnetism.

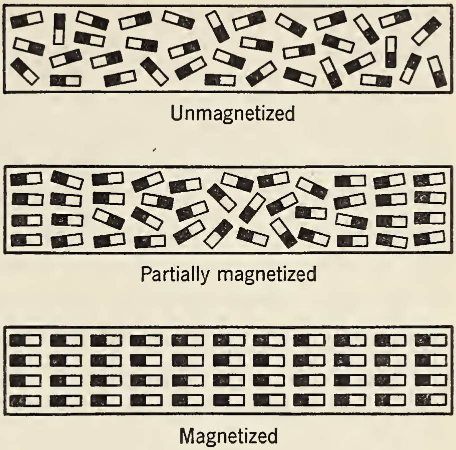



FIG. 13–7. In an unmagnetized bar the molecules are believed to be tiny magnets, arranged in no particular order. When the bar is partially magnetized, more of the particles are arranged parallel to the length of the bar. When the bar is saturated with magnetism, the particles are all in order as shown.

When we heat or tap a bar magnet as it is held in an east-and-west line, the molecules are disturbed and tend to swing around until they are no longer in regular order. The magnetism is reduced in strength or removed completely.

It is believed that the molecules of hard steel are more difficult to disarrange after the steel is magnetized. Hence hard steel makes a magnet that is more permanent.

**290. How does the earth act as a huge magnet?** William Gilbert, physician to Queen Elizabeth, was fond of experimenting. He made a "little earth" out of magnetite or lodestone. Then he placed tiny pivoted magnets at various positions on his "little earth," which he called "terrella." He found that they behaved in a manner similar to that of compass needles placed at various places on our earth. From his experiments and for other reasons, scientists are agreed that the *earth acts as if it were a huge magnet.* It acts much as if a bar magnet 8000 miles long were placed inside the earth, extending from one pole to the other.

The north magnetic pole of the earth has been found at about 96° west longitude, and 70° north latitude. You will notice that the north magnetic pole of the earth is about 1400 miles from the north geographic pole. The north-seek-

ing pole of a compass needle is attracted to the north magnetic pole, but not to the north geographic pole.

The south magnetic pole of the earth was discovered to be at about 72° south latitude and 155 east longitude. The south-seeking pole of any magnet at any place on the earth is attracted to this pole. You will notice, too, that the south magnetic pole does not coincide with the south geographic pole.

291. **Why does not the compass needle point to the true north?** At a few places on the earth, the north-seeking pole of the compass does point to the true north. If you look at the map of Figure 13–8, you will find a line marked zero. It passes through Lake Superior, Michigan, Ohio, Kentucky, Tennessee, North Carolina, and South Carolina. A compass needle placed on this zero line points toward the north magnetic pole and also to the north geographic pole, because they both happen to be practically in line with one another as we follow this line northward.

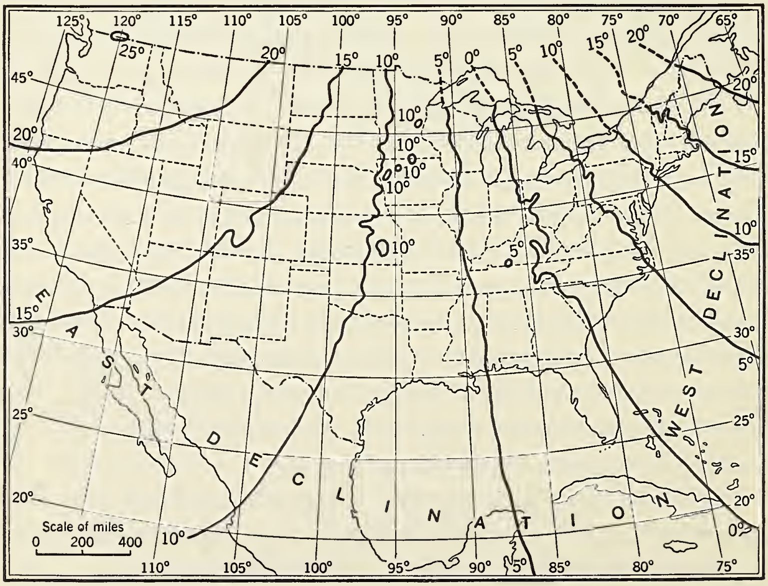



Fig. 13–8. This map shows magnetic declination.

The north-seeking pole of a compass needle placed on the 10° line which is east of the zero line will point to the north magnetic pole, but *it will point 10° west of the north geographic pole.* At New York City, for example, a compass needle points about 10° west of north. The angular difference which the compass needle makes with a true north-and-south line at any place is called the *magnetic declination* of that place.

If we go down to Austin, Texas, we find that the compass needle points about 10° east of north. This city is in an area where the magnetic declination is toward the east. Now it is easy for us to see why the sailors on the ships that Columbus sailed became alarmed when they found that the magnetic declination of the compass needle kept varying from the true north as they sailed on and on into new waters.

**292. How is electricity produced?** More than 2500 years ago the Greek philosopher Thales (thā′lēz) discovered that pieces of amber which had been rubbed with silk would attract *pith,* the light spongy material which occupies the central portion of some plant stems. The name *electricity* was given to this *phenomenon,* because the Greek word for amber is *electron.*

It has been found that many substances can be electrified by friction. Such electricity is known as *frictional,* or *static,* electricity. For example, glass may be rubbed with silk; sealing wax may be rubbed with flannel; hard rubber may be stroked with catskin. If your hair is dry, it may be electrified by combing it with a rubber comb. You electrify the leaves of a pad of paper if you write rapidly on the top sheet with a lead pencil. Your own body becomes electrified if you shuffle your feet over a rug in which the pile, or ends of threads used in weaving, is deep.

**293. How can the presence of electric charges be shown?** An instrument to detect the presence of an electric charge is called an *electroscope.* A simple electroscope can be made by taking a ball of pith and suspending it from a support by

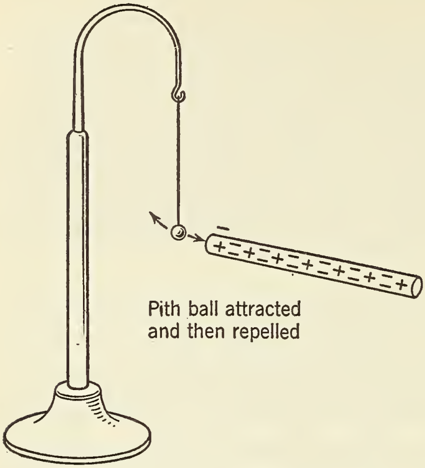



FIG. 13–9. The electrically charged rod shown in this figure has more electrons than protons. It is negatively charged with electricity. The light pith ball is first attracted to the rod and then repelled.

means of a *silk* thread. [See Fig. 13–9.] If you hold near the pith ball a glass rod which has been rubbed with silk, you will find that the pith ball is first attracted to the glass rod. It sticks to it for a few moments, and it is then violently repelled.

Another test for the presence of electric charges is to inflate two toy balloons until they are about six inches in diameter. Tie the openings tightly and suspend the balloons side by side by means of two pieces of silk thread, each about one yard in length. The two balloons should just touch each other. If you lift one of them and rub it briskly between your hands or with a piece of cloth it will be electrified. When you release it, the two balloons will repel each other with considerable force.

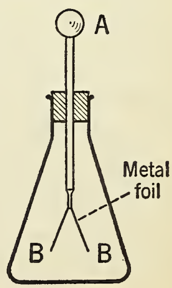



FIG. 13–10. If an electrically charged rod, one with an excess of electrons for example, is touched to the knob of the electroscope, the electrons flow down through the rod to the strips of metal foil. They are both charged with electricity of the same sign, and repel each other. The separation of the strips of foil proves that the rod was electrified.

A type of electroscope that is widely used in laboratories consists of a glass flask, in the stopper of which a metal rod is supported. The top of the metal rod ends in a flat disc or in a metal ball. From the lower end, two strips of metal foil are suspended. When an electrified rod is brought near the knob of such an electroscope, the strips of metal foil repel each other, and stand at an angle, as shown in Figure 13–10. They fall and hang side by side when the charged object is removed.

**294. There are two kinds of electrical charges.** First electrify a hard-rubber rod by rubbing it with catskin, and then suspend the rod in a wire stirrup which is supported by means of a silk thread. Of course the rod is now free to move. [See Fig. 13–11.] Then hold near the suspended rod a second

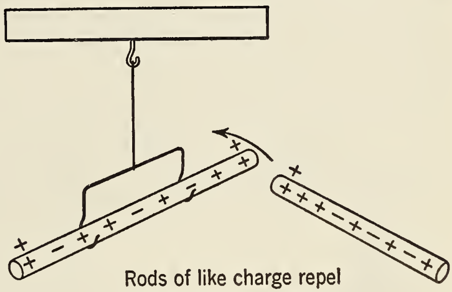



FIG. 13–11. Both rods *are deficient in electrons.* The two positively charged rods repel each other, according to the law of electrical repulsion.

rod of hard rubber, which has been electrified in the same manner. The two electrified rods *repel* each other, and the suspended rod swings around to get as far as possible from the rod you are holding. This experiment shows that *like charges of electricity repel each other.*

Next electrify a glass rod by rubbing it with silk and then hold it near one end of the suspended hard rubber rod. You will find that they attract each other. Each one is charged with a different kind of electricity. This experiment proves that *unlike charges of electricity attract each other.* It can be shown, too, that one glass rod charged by rubbing it with silk will repel another glass rod, similarly charged.

We conclude: (*a*) that there are two kinds of electricity; (*b*) that like charges repel; and (*c*) that unlike charges attract. Benjamin Franklin used the term *positive electricity* for the kind of electricity which is produced by rubbing glass with silk. He used the name *negative electricity* for that kind of electricity which is produced by rubbing hard rubber with catskin. As a matter of fact, both kinds of electricity are produced in equal amounts at the same time. When we charge a glass rod by rubbing it with silk, the *silk* is charged negatively.

**295. What are electrical conductors?** Just as it is possible for heat to travel along a conductor, so we find that electricity may be led along a *conductor*. There is this difference, however: heat travels slowly, even along the best conductors. Electricity travels with a speed approximately that of light, which is more than 186,000 miles per second. [See Fig. 13–12.]

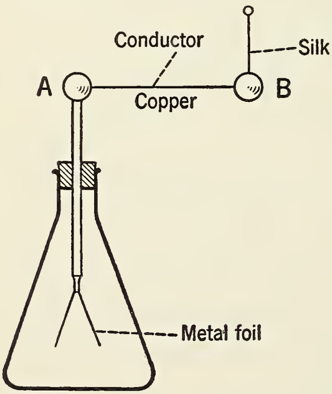



FIG. 13–12. We find that heat is led along some materials more readily than along others. In the same manner, some materials conduct the electron stream, or the electric current, much better than others do. Silver is the best conductor known. Copper is second to silver. Many conductors are made of copper. If a charged rod is applied to B, part of its charge is conducted to A.

As a rule, metals are good conductors of electricity. Silver is the best conductor of electricity known. Copper is the next-best conductor of electricity. The wires that conduct the electricity to your home are probably made of copper. The wires in your home are made of copper. Telephone and telegraph wires are made of copper, or of iron. Aluminum too is a good conductor, but not so good as copper.

**296. What are electrical insulators?** It can be shown by experiment that some substances do not let electricity pass through them easily. They offer resistance to its passage, and are known as *insulators*. Some of the most common insulators for electrical use include porcelain, glass, rubber, silk, paraffin, shellac, bakelite, mica, and dry air. The case of your telephone receiver is probably made of bakelite. There are no perfect insulators. On the other hand, there are no perfect conductors. All substances offer some resistance to the passage of electricity through them. Salt water conducts electricity much better than fresh water does. Green, unseasoned wood is a much better conductor than is dry wood.

The wires used in our homes are insulated by being covered with rubber. The wires are inserted in a flexible metal cable to protect the insulation and prevent its wearing off. Bell wire is usually wound with two layers of silk thread or of cotton thread. It may then be coated with paraffin. The insulation on wires serves two purposes: (*a*) it prevents a person from getting a shock by accidentally touching a wire that is carrying a current; (*b*) it prevents two wires from touching each other and causing the disturbance which we call a *short circuit*.

**297. What is the theory of electricity?** We know that electricity heats our flatirons and bread toasters, rings our doorbells, gives us light, operates our telephones and our radios, drives our vacuum cleaners, washing machines, and refrigerators, and does many other remarkable things. Naturally, men have been interested to learn what that mysterious force which does so many different things can really be. The *electron theory* explains many of the facts about electricity, and for that reason it is rather generally accepted today.

At various times we have had occasion to speak of molecules. We have learned, too, that molecules are composed of atoms. The word *atom* came from the Greek, and literally means something which cannot be cut in two, or divided. For centuries men agreed that the atom is indivisible. Now

we have a different picture of the atom. Scientists use enormous machines to " smash the tiny atom." What do they find?

*a*) All atoms have a nucleus which consists in part of particles called *protons*. The protons are small and dense, and carry a charge of positive electricity.

*b*) There are also *electrons* revolving around the nucleus, much as the planets revolve around the sun. The electron is about 1/1840 as heavy as the lightest atom known, which is the hydrogen atom. The electron carries a negative charge of electricity.

*c*) There are some other particles in the atom, too. In our study of general science, however, we are not concerned with the other particles.

From this theory of the structure of the atom, we picture a glass rod as made up of molecules and atoms. The atoms in turn are composed of positively charged particles or protons, and of negatively charged electrons. If the number of positive charges just equals the number of negative charges, then the glass rod is not electrified at all. When we rub the glass rod with silk, many of the electrons leave the rod and go to the silk. That leaves the glass rod *deficient in electrons*. It now has a *positive charge*, or we say that it is charged with *positive electricity*.

By taking electrons with their negative charges away from it, we have made it positively charged. If we test the silk, we find that it is negatively charged, because it has an excess of electrons. If we wrap the glass rod up in the silk, and test both of them together by holding them near an electroscope, we find that they show no signs of electrification. There is neither an excess nor a deficiency of electrons.

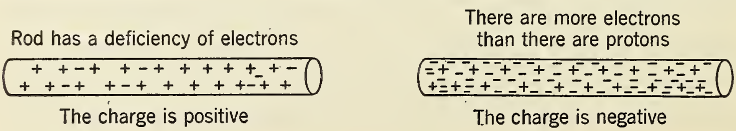



FIG. 13–13. One rod is positively charged; one, negatively.

Suppose we start with a hard-rubber rod. It has an equal number of positive and negative charges. It is not electrified. When we rub it with catskin, the rubber seems to be more greedy for electrons than is the catskin, and it takes extra electrons from it. Now the rubber or vulcanite rod has an excess of electrons. It is negatively charged. If we test the catskin, we find that it has a positive charge. [See Fig. 13–13.]

From such experiments the following conclusions may be drawn: (*a*) if an object has an excess of electrons, it is negatively charged; (*b*) if an object is deficient in electrons, or has an excess of protons, it is positively charged; (*c*) if the number of positive charges is just equal to the number of negative charges, there is no electrification at all.

**298. How is lightning related to electricity?** Nearly all American boys and girls have read the story of Benjamin Franklin and his kite. When he flew his kite during a thunderstorm, he was able to prove that lightning and frictional electricity are one and the same thing. It is not safe for anyone to try Franklin's experiment, and it is rather remarkable that Franklin was not killed while he was performing it. Some others who tried that experiment were killed.

**299. What causes lightning?** A cloud becomes electrically charged, possibly to some extent by the friction of the wind, but probably more by the condensation of its water vapor. Ordinarily, air is an insulator, but when the electric charge of the cloud becomes great enough, it may "break down the insulator." Then a huge electric spark, similar to the tiny one we produce when we shuffle across a carpet and then hold a finger near a piece of metal, or some other object or some person, leaps across from one cloud to another or between a cloud and an object on the earth. That huge spark is the *lightning flash*. We are accustomed to say that the object on the earth has been "struck by lightning." [See Fig. 13–14.]

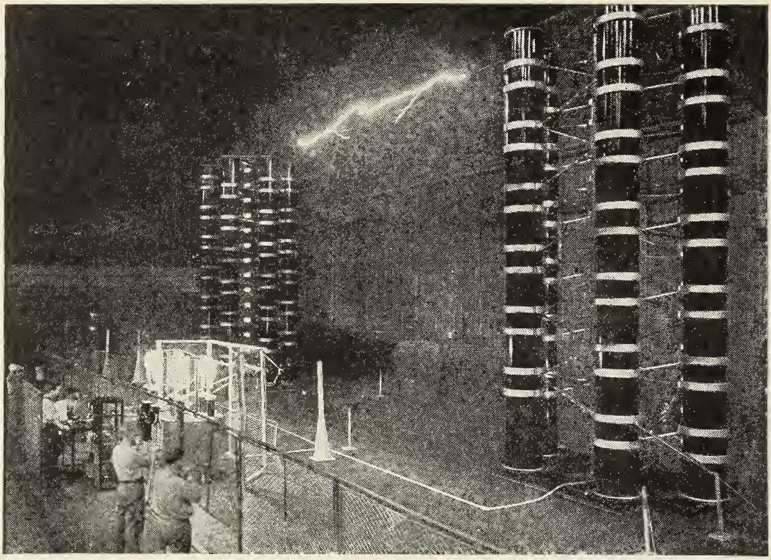


FIG. 13–14. These towers are charged with electricity, but one set has a much higher voltage than the other set. Hence an electrical discharge occurs from one to another. This affords us an excellent example of man-made lightning. (*Courtesy General Electric Co.*)

**300. How are lightning rods used to protect buildings?** The lightning rod is an invention of Benjamin Franklin. There is some difference of opinion as to whether lightning rods actually do protect buildings against lightning. Fire-insurance companies have collected data which show that a properly installed lightning rod is a protection to a building. They also show that a poorly installed rod is a menace. One should be sure of the following.

*a*) That the rods are made of good conductors, such as copper or iron.

*b*) That the rods are large enough so that they will not be melted by heavy charges of electricity which may travel along the rods.

*c*) That the rods extend a few feet above the highest part of the building and that they end in several points. Pointed objects rapidly discharge an electrically charged object.

*d*) That the copper cable from each rod should extend down into the earth to such a depth that it will always be in contact with *damp* earth. The end of the cable may be attached to a metal plate which is buried underground.

*e*) That metal roofs and gutters should be connected with the rods. [See Fig. 13–15.]

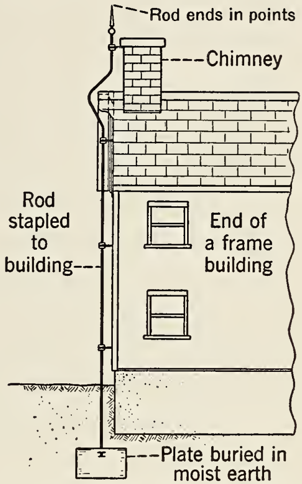



FIG. 13–15. The lightning rod which is stapled to the end of this dwelling house helps to keep the voltage of clouds which are passing over the house from getting high enough to cause a dangerous lightning discharge. Hence it is less likely to be "struck by lightning." The metal framework of a skyscraper serves as an excellent protection. A tall tree near a dwelling house protects the house.

If a positively charged cloud is passing over a building fitted with lightning rods, electrons flow from the earth upward through the rods and escape rapidly from the pointed ends. They reach the air molecules and help to neutralize the charge on the cloud. Thus they may reduce its electrical pressure before it gets high enough to break across the air gap and damage the building.

A large tree standing not too far from a house affords good protection against lightning. Its roots extend down into moist earth; its sap is a fairly good conductor; its pointed branches permit electrons to flow readily and help neutralize the charges of the passing clouds.

**301. What precautions can you take against lightning?** One of the safest spots during an electrical storm is in a large building with a steel framework. In such a storm, you can

see how lightning plays around the outside walls of a building with a steel framework, but the building is not damaged, nor are the persons inside injured. Solitary trees are often struck by lightning, but the trees in a forest are seldom injured. You are reasonably safe in the heart of a forest, but you should not take refuge under a solitary tree during a thunderstorm. If the lightning charge does break across the air gap and strike the tree, you may be shocked by the lightning, or you may be struck by falling branches from the tree.

You are safer inside the house than you are outside. It is not a good plan, however, to sit or stand near metal pipes or fixtures that are connected with the ground. Lightning arrestors are used with telephones and radios. It is doubtful, however, whether you are as safe using the radio or the telephone during a thunderstorm as you are away from these instruments. One seems to be safe in an automobile. For many years one of the authors of this book has watched the newspapers and never read of a single case where an automobile or a person in an automobile was struck by lightning.

## QUESTIONS

1. Why is a piece of magnetite sometimes called a lodestone?
2. What are the poles of a magnet?
3. How would you make a magnet out of a piece of knitting needle?
4. Is a magnet destroyed by being broken?
5. How can you remove the magnetism from a bar magnet?
6. How is the compass needle affected by masses of iron around a ship?
7. Magnets are often bent into a horseshoe shape. Can you suggest an advantage such a shape may have?
8. Can you find out what kind of compass is used on a submarine? If so, be prepared to tell the class about it.
9. Do you think that paper is transparent to magnetism? Experiment until you can give a reason for your answer.

10. Can you find out what kind of compass is used on an airplane? If so, make a report on such a compass to the class.

11. Sometimes the balance wheel and also the hairspring of a watch become magnetized. Then the watch does not keep good time. Would you suggest pounding it with a hammer or heating it red hot to remove the magnetism? Ask some jeweler how he demagnetizes a watch.

12. Refer to Figure 13–6. Do you think that lines of force about a magnet are closed curves? Do they seem to cross one another? Where are they most closely crowded?

13. Examine the map of the United States shown in Figure 13–8. What is the magnetic declination of Washington, D. C.? of Los Angeles? of San Francisco? of Denver? of Detroit? of Chicago? of Salt Lake City? of Minneapolis? of New Orleans?

14. When your hair is very dry, and you comb it, the separate hairs seem to repel each other. Explain.

15. When you write rapidly on a pad of paper, the top sheet may stick to the second one. Explain.

16. Do magnetism and static electricity seem to resemble each other in any way? If so, how?

17. What precautions should one take during a thunderstorm?

18. Which do you think is more likely to be struck by lightning, a solitary tree in the center of a field or a tree in the center of a forest? Explain.

19. Which do you think is more likely to be struck by lightning, a house in a closely built-up portion of a city or a solitary house in the country? Explain.

## *Something for You to Do*

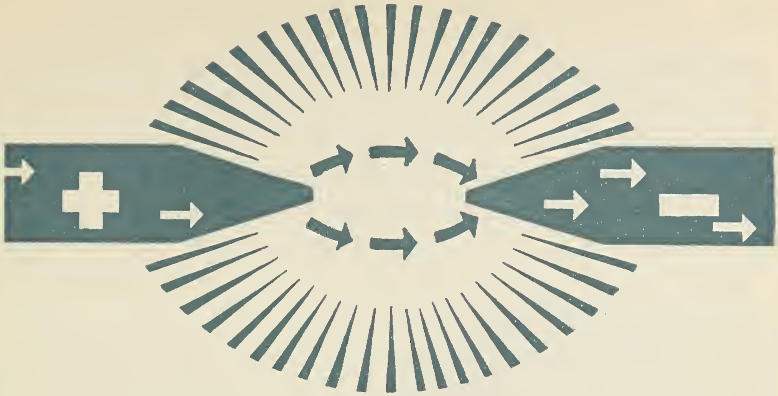
Drive a ten-penny nail through one end of a board. It must be vertical. Place the board on the sill of a south window. The board must be horizontal. At exactly noon, mark the end of the shadow of the tip of the nail. (That should be the shortest shadow which the nail casts.) A line drawn through the tip of the shadow and the center of the base of the nail is a north-and-south line. Place a compass needle on this line and see what the magnetic declination is in your city or your home.

## THINK ABOUT THESE!

1. What is meant by the term *electric current*?
2. How is the electricity that lights your home produced?
3. In what form do we buy electricity?

## WORDS FOR THIS CHAPTER

**Circuit.** The entire path traveled by an electric current.
**Volt.** The unit used to measure electrical pressure.
**Ampere.** The unit used to measure the strength of an electrical current.
**Ohm.** The unit used to measure electrical resistance.



CHAPTER 14 ——————— UNIT 7

# How Is Current Electricity Produced?

**302. How do static electricity and current electricity differ?** The kind of electricity that we studied in the preceding chapter is sometimes called *frictional* electricity, because it is so often caused by friction. It is known as *static* electricity, too, because it refers to electricity which is at rest, or passive. An electric charge at rest cannot do any work. In our study of *current* electricity we shall deal with an electric charge in motion, or with what is called the *electric current*. We can use the electric current to do work.

**303. How can one produce an electric current?** In A.D. 1790 an Italian scientist named Galvani was experimenting on a recently killed frog, which was suspended by means of a copper wire attached to its leg. When he touched the frog's leg with a knife, the frog twitched convulsively. He thought the twitching was caused by electricity in the frog's leg. He was wrong in his opinion, but his observation led to more fruitful discoveries. It often happens that one man makes

some discovery that attracts attention. Other persons begin to experiment; and other discoveries of even greater importance are the result.

It was Alessandro Volta, a countryman of Galvani, who began some experiments with different elements after Galvani had made his discovery. [See Fig. 14–1.] Volta took glass

FIG. 14–1. Alessandro Volta (1745–1827) was a distinguished Italian physicist. He was the inventor of the voltaic cell. The volt is named in honor of Volta. His work led to the use of current electricity for practical purposes, but science has traveled a long distance since Volta did his pioneer work.

jars and used in them solutions of acids or other compounds. Then he dipped into the solutions two rods or strips of *different* elements. When he joined the tops of the elements with a conductor, he found that a current of electricity flowed through the conductor. In such manner the *voltaic cell* was born. It was named for Alessandro Volta.

**304. How is the voltaic cell made?** Let us fill a glass tumbler half full of dilute sulfuric acid. We then dip one end of a carbon rod into the acid. We cannot see any evidence that the acid attacks the carbon rod at all. If we remove the carbon rod, and dip one end of a zinc rod into the dilute acid, there is a different story. In a short time we see bubbles

of gas that *seem* to be coming from the zinc. In reality they come from the acid as the zinc and acid interact with each other. Some chemical action is taking place. The gas, which is hydrogen, comes from the acid and clings to the zinc or escapes to the surface of the liquid. Of the two unlike elements that we have tested in the acid, one of them is not acted upon by the acid, but the other one is attacked rather vigorously.

Suppose we try dipping both rods into the acid at the same time, holding them in clamps, as shown in Figure 14–2. The

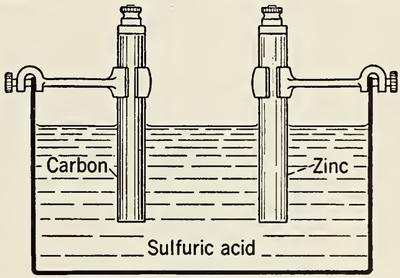



FIG. 14–2. A voltaic cell consists of two unlike elements immersed in a fluid which acts chemically upon one of them. In this case, the carbon is not attacked by the acid, but the zinc and acid do interact.

action between the acid and the zinc continues as before, but there is no action on the carbon. When we attach a short piece of insulated copper wire to the upper end of each rod, and then connect the free ends of the wires to an electric buzzer, we find that something causes the buzzer to sound. We call this force electric current.

From such experiments it has been learned that a voltaic cell consists of the following parts.

*a*) Two unlike elements, such as carbon and zinc. No current is produced if one uses two pieces of copper, two of carbon, or two of zinc.

*b*) Some chemical, such as sulfuric acid, which will act chemically upon *one* of the elements selected. It does not act upon the other element. You can make a voltaic cell by using carbon and zinc rods in a solution of salt water.

In the voltaic cell the element which is not acted upon by the solution is called the *positive plate* of the cell. The ele-

ment which is attacked by the solution is called the *negative plate* of the cell. It is possible to show by experiment that the positive plate is deficient in electrons, and that the negative plate carries an excess of electrons. *The electric current consists of a stream of electrons flowing through a conductor.*

305. What is an electric circuit? Let us refer to Figure 14–3, which shows a diagram of a simple electric circuit. To

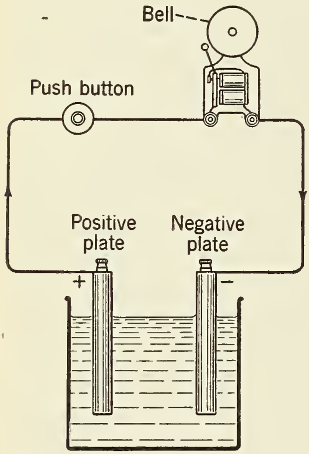



FIG. 14–3. In this simple electric circuit we assume that the current flows from the positive terminal of the cell through the push button, which of course must make a closed circuit, through the bell, and back to the negative plate of the cell. It then flows through the liquid of the cell from the negative plate to the positive.

the top ends of both the positive and negative plates, a small threaded screw and thumb nut are attached. They are called *binding posts.* They make it easy to attach the insulated wire to the plates. Before the wire is attached, however, the insulation must be scraped away from the end of the wire so that the bare metal comes into contact with the nut of the binding post. In any electrical connection, the two surfaces must be clean and free from tarnish, and the two surfaces must then be fastened together firmly. If a permanent connection is desired, the two clean surfaces may be soldered together. The insulation must be stripped from about one inch of the other ends of the wires before they are attached to the binding posts of the bell or of the push button.

It is important to remember that electricity is not likely to go skipping across air gaps, because they offer too much re-

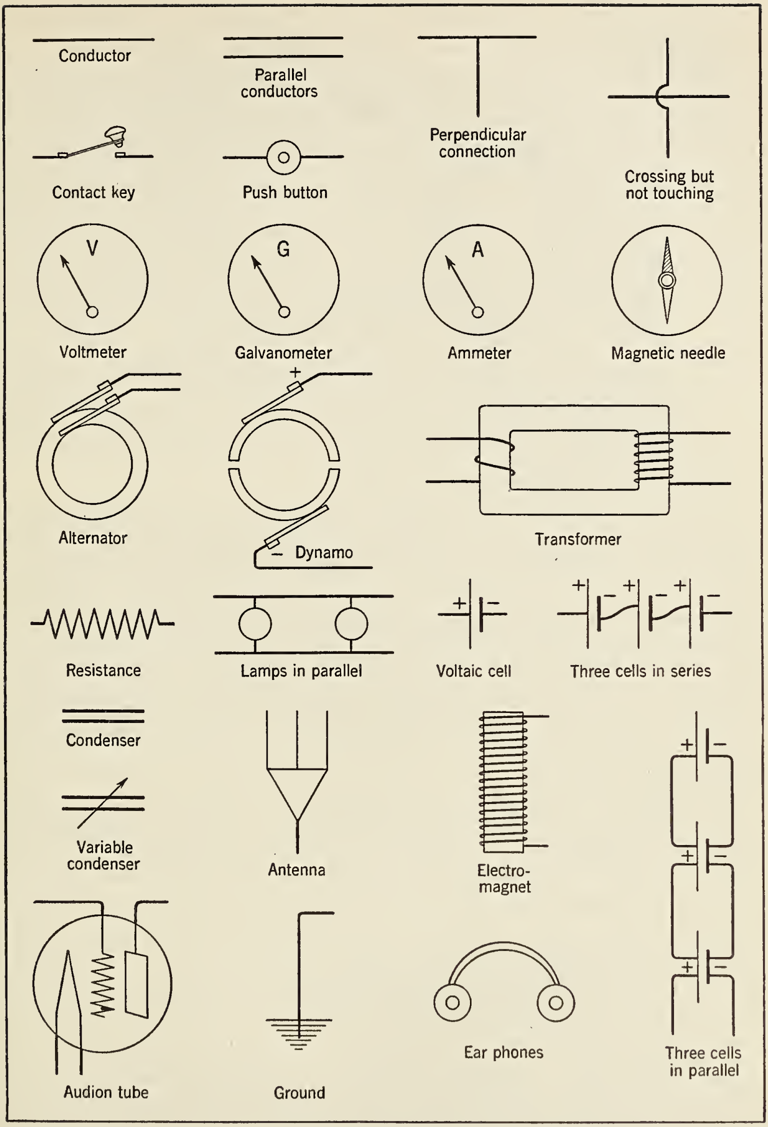



Fig. 14–4. When the electrician makes a wiring diagram, he uses many conventional drawings to represent both connections and instruments. Instead of trying to make a drawing of a voltaic cell, for example, it is simpler to use the convention shown here.

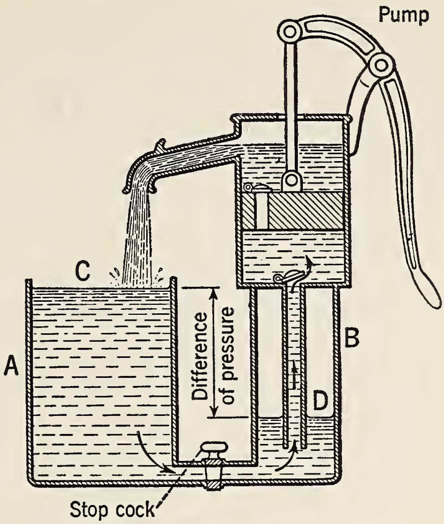
sistance; but that it usually flows through a circuit that is made up entirely of conductors. Let us refer to Figure 14–3, and trace the path of the current through the complete circuit that is made when we press the push button. We may begin at the positive plate. We assume that the current flows through the wire to the push button, through its metal contacts, through the wire to the bell, through the metal windings of the bell itself, through the wire from the bell to the negative plate, and then through the liquid in the cell back to the positive plate. When we press the push button, we "make" or "close" the circuit. When we stop pushing, a spring "opens" or "breaks" the circuit. *An open circuit* is one in which there is a break or gap in the connection at some point, across which no current can flow.

In assuming that the current flows from the positive plate of a cell through the wire to the negative plate, we are following the theory of Benjamin Franklin. According to the electron theory, he was probably wrong. The modern theory assumes that the current flows from the negative plate through the wires to the positive plate, or through the *external circuit.* Then through the *internal circuit,* from the positive plate to the negative plate.

**306. Some conventional diagrams.** Some of the apparatus and some of the appliances used in electrical work are rather complicated, but many simple conventional diagrams are used to represent electrical devices. For example, a rather thin, long line represents the positive plate of a voltaic cell, and a short, thick line represents the negative plate. [See Fig. 14–4.] In the diagrams in this book, you will find such conventions in use.

**307. How is a voltaic cell like a pump?** We know that water flows downhill because the pressure of the water at the higher elevation is greater than the pressure at a lower elevation. If we have a pump arranged like that of Figure 14–5, it is possible to pump water into the tank fast enough to keep the level of the water at C continually. As the water flows

FIG. 14–5. In this pump circuit, water flows from the tank at A through the stop cock into B, because the water level is higher at C than it is at D. To maintain a constant difference in pressure between the two tanks, the pump must keep water flowing into A as fast as it flows through the stop cock.




into D, it is pumped up again into C to maintain the water pressure.

In a similar manner, an electric current will flow in a circuit if the pressure at some point in the circuit is greater than it is in other parts of the circuit. A voltaic cell keeps a current flowing continuously in a circuit because it acts like a pump. At the expense of chemical energy, the voltaic cell keeps building up pressure at the positive plate. All the time that the zinc is going into solution in the acid, *chemical energy is*

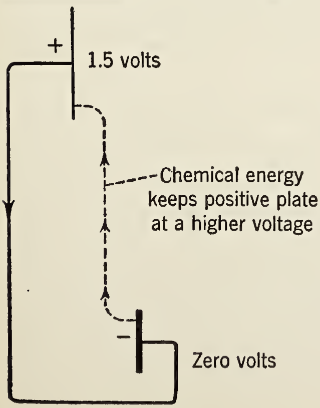



FIG. 14–6. A voltaic cell is like a pump in one way. The positive plate must be kept at a higher pressure than the negative plate, if current is to flow through the circuit. The action of the acid upon the zinc supplies chemical energy, which is changed into electrical energy. In such a manner, pressure is built up constantly.

*being changed into electrical energy.* The electrical energy keeps one plate of the cell at a higher pressure, or *voltage,* than that of the other plate. [See Fig. 14–6.] We may think of the *volt* as a measure of the unit of the electrical pressure, which pushes or pulls a stream of electrons through an electrical circuit.

**308. What are some of the electrical units?** A number of units are used for measurement in the field of electricity, but at this time we shall mention only three of them.

*a) The volt is the unit of pressure.* In order to measure electrical pressure, an instrument called a *voltmeter* is used. The unit used for such measurement is the *volt,* which is named in honor of Volta.

The company from which you buy your electrical energy supplies electricity to you at from 110 to 120 volts, as a general rule. For the operation of a trolley car, the trolley wire generally has from 550 to 660 volts more than that of the rails which complete the circuit. From Boulder Dam, electricity for power purposes is transmitted at 287,000 volts.

*b) The ampere is the unit of current flow.* We may have just a tiny trickle of water flowing through a pipe, or we may have a large stream. The amount that will flow in any given time increases as we increase the pressure. It will also increase if we use a large pipe which offers little friction or resistance. It is possible to measure the rate of flow of water in gallons per minute.

The amount of electricity which flows in a wire may be either small or large. It depends upon the number of electrons in the electric stream. The unit of current strength is called the ampere. It is measured by an instrument called an *ammeter.* Figure 14–7 shows the dial of an ammeter used to show whether an automobile battery is being charged or discharged and at what rate in amperes. For example, when the car's lights are turned on, from two to six amperes of current flow through their filaments.

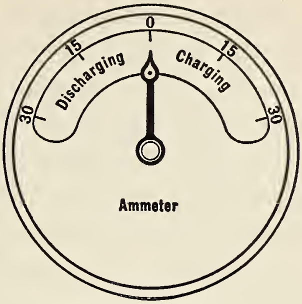



FIG. 14–7. An ammeter is one of the instruments found on the panel of an automobile. When the generator is running, the needle shows that the battery is being charged. When the battery is in use, the needle shows that the battery is discharging.

c) *The unit of electrical resistance is the ohm.* Water flowing through a pipe encounters some friction. In a similar manner, electricity encounters friction, or *resistance,* in flowing through a wire. The unit of electrical resistance is the *ohm.* The better the conductor, the less its resistance. Copper and silver offer less resistance than other substances do.

One would expect that a long wire would offer more resistance than a short wire does. That is true. In fact, if we *double* the length of a wire, we *double* its resistance in ohms. At first thought, one might expect a large wire to offer more resistance than a small one. Such is not the case, however. A wire of double the diameter of an exactly similar wire has only one-fourth as much resistance. If we compare electrical resistance with the friction which flowing water encounters, it is not strange that a small wire has more resistance than a large one. A quantity of water meets more resistance in flowing through a pipe a pinhole in diameter than it does in flowing through a pipe three inches in diameter. In a similar manner, a narrow lane offers more resistance to the flow of traffic than does a broad highway. Congestion (friction or resistance) always occurs at the bottlenecks along a highway.

**309. How much current will flow in a circuit?** Once more we may refer to flowing water as a comparison. The amount of water that will flow through a pipe depends upon two things: (*a*) the water pressure; (*b*) the pipe's resistance.

In a similar manner, the amount of current that flows in an electrical circuit depends upon two things: (*a*) the electrical

pressure, or the voltage; (*b*) the resistance in ohms offered by the circuit. If we wish to increase the *amperage* (ăm·pēr′ĭj), or the amount of current flowing in a circuit, we may either raise the voltage or lower the resistance. In fact, one volt is that unit of pressure which will cause a current of one ampere to flow when the resistance is one ohm. Georg Simon Ohm, a German physicist, stated this fact in a law which bears his name. His law may be concisely stated as follows:

$$\text{amperes} = \frac{\text{volts}}{\text{ohms}} \cdot$$

For example, assume that the pressure in a circuit is 120 volts. The resistance is 40 ohms. The amount of current that flows in the circuit is 3 amperes ($120 \div 40$).

The amount of current flowing along a conductor, a wire for example, is not unlike the amount of traffic which flows along a highway. State troopers along the highway straighten out "traffic snarls" and use "pressure" to keep the traffic moving. If the highway is broad, it offers little resistance to the moving cars. As the pressure increases, more traffic flows. Reducing the resistance increases the flow of traffic, too.

**310. The dry cell is widely used.** Since the time when Volta made the first voltaic cell, many different kinds of cells have been made. If we keep in mind the fact that two unlike elements must be used, and that there must be a fluid which acts upon one of them, we can understand why there are many possibilities. For example, gold and zinc have been used as elements. Platinum and zinc have been tried. Other combinations include copper and zinc, carbon and zinc, and iron and zinc. Such solutions as sulfuric acid, hydrochloric acid, blue vitriol, sodium hydroxide, and salt water have been used. No combination is perfect. A copper wire and a zinc wire thrust into a lemon will give some electrical current. [See Fig. 14–8.] The element zinc seems to be the most satis-

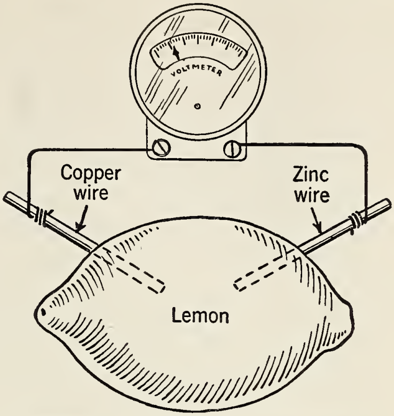



Fig. 14–8. The acid in a lemon is capable of acting upon a zinc wire and producing a simple voltaic cell when it is used with a copper wire. Do you think that a sour apple used instead of the lemon would produce the same result?

factory element that has ever been found for making the negative plate. It is easily acted upon, and it is not too expensive. Carbon is inexpensive and it is not attacked by the liquids used in cells. These elements, carbon and zinc, are used in the common *dry cell*, which is the most satisfactory cell that has ever been devised.

In the making of a dry cell, a sheet of zinc is rolled up into a cylinder, or cup. [See Fig. 14–9.] A carbon rod is placed

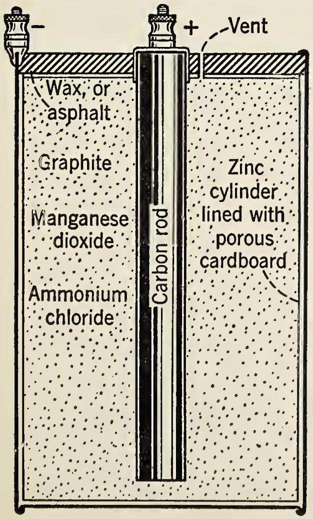



Fig. 14–9. The dry cell varies in size from the tiny ones used in flashlights, radio batteries, etc., to the rather large ones that are used for ringing door bells. It is an interesting fact, too, that a tiny cell gives just as high a voltage as a very large cell. It does not furnish so many amperes of current, however.

in the center of the cylinder, which is then filled with a paste made of sal ammoniac, water, manganese dioxide, particles of carbon, and zinc chloride. The top is covered over with pitch or sealing wax to keep the water from evaporating. A tiny opening is left in the top to permit gases to escape.

**311. Why is the dry cell useful?** From what we have learned about the making of a dry cell, we must conclude that it is not *dry* at all. It contains a moist paste, and it works just as well when lying on its side as it does when standing erect. Other cells cannot be used except in an erect position. A new dry cell furnishes about 1.5 volts of pressure. The resistance of the material inside the cell is so small that the dry cell may furnish from 30 to 40 amperes of current when the external resistance is zero. The external resistance includes the resistance of everything which is attached to the binding posts, but outside the cell itself. The cell runs down fairly rapidly if it is used up to its capacity for some time, but it recovers to some extent when the cell is permitted to stand on open circuit. When the paste inside has "eaten through" the zinc cylinder, the cell dries out, and is of no more value. It cannot be recharged.

Dry cells are used in operating flashlights, doorbells, and radio sets, and for many other purposes where a low voltage and not too high an amperage are to be used for a short time.

***312. How are cells grouped?** If a single cell does not give sufficient voltage or enough current for our needs, it is possible to group two or more cells to give more voltage, more current, or possibly both. Two methods are in common use:

*a*) *Series grouping.* One dry cell gives about 1.5 volts pressure. If we join the positive of one cell to the negative of a second cell, the positive of the second to the negative of a third, as shown in Figure 14–10, we have three cells grouped in *series.* It is similar to a serial story which is continued in the next issue of a magazine. Such a grouping of cells raises the voltage. In fact, each cell that is added will add its voltage. Three dry cells in series furnish 4.5 volts

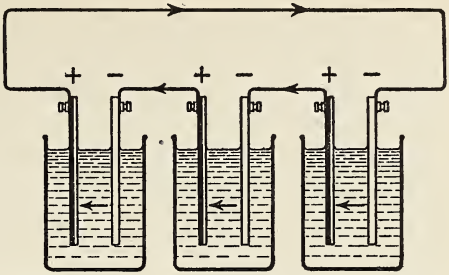


FIG. 14–10. In this diagram we have three cells grouped in series. They give three times as much voltage as a single cell.

(3 x 1.5). Four dry cells in series furnish 6 volts. Of course the current must flow through each of the cells in turn, too, and it will encounter three times as much cell resistance, or internal resistance. When the external resistance due to the wires and appliances outside the cell is relatively small, we get little more current by series grouping. If that resistance is relatively large, we get a decided increase in the amount of current flowing through the circuit. Hence, series grouping always raises the voltage, and it may raise the amperage.

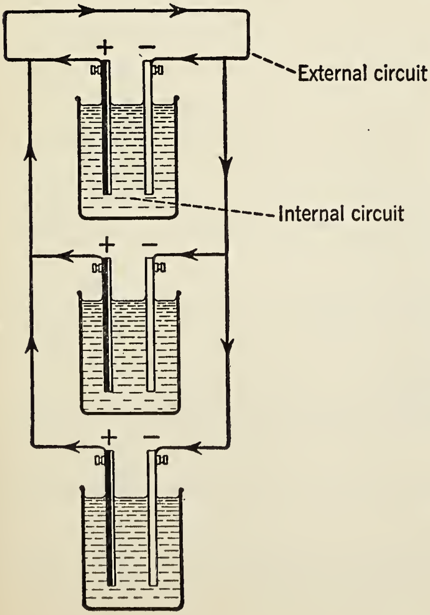



FIG. 14–11. When three cells are grouped in parallel, they do not give any higher voltage than a single cell furnishes, but it is possible for them to furnish more amperes of current. The resistance within the cells is reduced by grouping them in parallel, as shown in this diagram. You will observe that the positive plate of each cell is joined to the positive plates of all other cells, and that all the negative plates are joined together, too.

*b*) *Parallel grouping.* We may group cells in parallel by joining all the positives together and all the negatives together, as shown in Figure 14–11. The current divides and a part flows through each cell. It is similar to the running of a story in the August issues of three different magazines, a part in each one. When cells are grouped in parallel, there is *never any increase in voltage, but there may be a decided increase in amperage.*

Since most of our incandescent lamps now need 120 volts for their successful operation, we can easily calculate that one would need to have at least 80 dry cells grouped in series to supply the voltage needed for home lighting ($120 \div 1.5 = 80$). That does not seem practical, and from that fact one can clearly understand why it is necessary to have machines called *dynamos* to generate electricity for operating lights, percolators, toasters, and flatirons, and for driving our electric motors. We need to study something of the effects of the electric current before we take up the study of the dynamo.

## QUESTIONS

1. How does a charge of static electricity differ from an electric current?
2. Of what does the voltaic cell consist?
3. What kind of energy does a voltaic cell use? What kind of energy does it produce?
4. What is meant by "breaking" an electric circuit?
5. Why do electricians use so many conventional devices in their wiring diagrams?
6. In what different ways is an electric current like a stream of water?
7. Which has the greater resistance in ohms, a copper wire or an iron wire, if both have the same length and the same diameter?

8. A copper wire of a given diameter has a resistance of 10 ohms. What is the resistance of a similar piece of copper wire which is four times as long as the first wire?

9. In order to have a high resistance, should a wire be long or short? thick or thin?

10. The electric current is believed to be a stream of electrons flowing along a conductor. It is like a stream of traffic. Do you expect to find more traffic congestion (resistance) on a narrow road or on a broad road? How does this apply to the ability of wires of different diameter to carry current?

11. Make a list of several uses for a dry cell.

12. Do you think you could connect enough cells in series to light an incandescent lamp that is designed to operate on a 120-volt circuit?

13. Do you think it is possible to join enough cells in parallel to light the lamp referred to in Question 12?

14. A bread toaster is connected to a 120-volt circuit. An ammeter shows that there are 6 amperes of current flowing in the circuit. What is the resistance of the coils of the toaster in ohms?

## *Something for you to do*

Fill a tumbler half full of dilute hydrochloric acid. (About one part of acid to five parts of water.) Stand a zinc strip or a zinc rod in the solution. What happens? Remove the zinc strip and repeat the experiment, using a strip of copper. Fasten one end of a coil of wire to one end of the zinc strip, and the other end of the coil to one end of the copper strip. Place the free ends of the strips in the acid solution, and put a small compass inside the coil of wire. Note how the compass needle is deflected. Then see whether you can get enough electricity out of the simple cell you constructed to ring a small bell. You may repeat the experiment with other strips of metal.

## THINK ABOUT THESE!

1. Have you ever wondered how electricity operates a fan or a vacuum cleaner?
2. How many different things in and around your home are run or operated by electricity?
3. What makes your electric iron get hot when you turn on the electric current?

## WORDS FOR THIS CHAPTER

**Electromagnet.** A device which has magnetic properties when a current flows through its coils.

**Helix.** A spiral coil of wire.

**Billets.** Short slabs or bars of metal.

**Armature** (är′mȧ·t͝ûr). As used in this chapter, a piece of soft iron, which may be placed across the poles of a magnet.

**Electrolyte** (ė·lĕk′trō̇·līt). The solution in a cell in which electrolysis takes place.

**Anode.** The plate, or electrode, which is attached to the positive terminal of the dry cells or the dynamo used with an electrolytic cell.

**Cathode.** The plate, or electrode, which is attached to the negative terminal of the dry cells or the dynamo used with an electrolytic cell.

**Graphite** (grăf′īt). A soft mineral substance which conducts electricity; it is used in the making of electrotypes, and also for lead pencils.

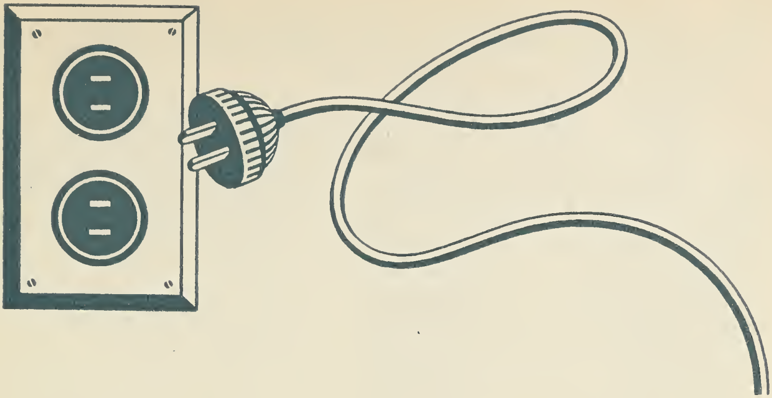
**Hydrometer** (hī·drŏm′ė·tẽr). An instrument for determining the specific gravity of liquids, or for testing batteries.

**Nichrome** (nī′krōm). An alloy which has a high melting point and offers considerable resistance to the electric current.

**Watt.** The unit used to measure electrical power.

**Watt-hour.** The unit used to measure electrical energy.

**Shunt.** One of the branches of a divided electric circuit.



CHAPTER 15 — UNIT 7

# What Can Electrical Energy Do?

**313. What can electricity do?** When you go out to look for a position, one of the things in which your prospective employer will be much interested is, "What can you do?" If you can do as many different things as electricity can, you will be a handy man to have around the house or in any employment you may undertake. In this chapter we shall concern ourselves with some of the effects of the electric current.

**314. How can one use the electric current to make a magnet?** Let us connect the ends of a piece of insulated wire, about two feet long, with a dry cell and a push button. We hold this wire *over* a compass needle and close the circuit. We notice that the needle is deflected, and tries to take a direction at right angles to the wire. [See Fig. 15–1.] If we hold the wire *beneath* the compass needle, we find that the needle is deflected in the opposite direction when we close the circuit. A Danish scientist, Hans Christian Oersted, performed this experiment in the early part of the nineteenth

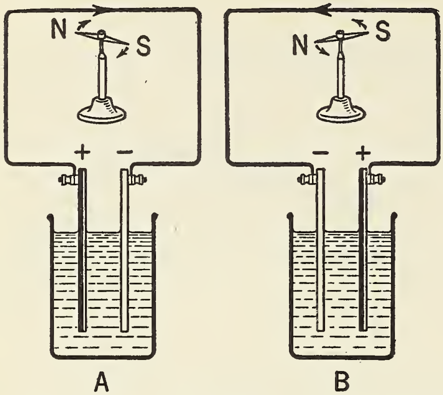


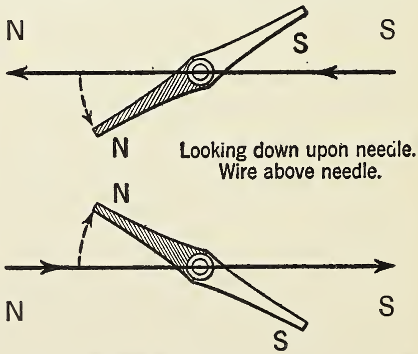

Fig. 15–1. Oersted was the first to discover that a current flowing through a conductor sets up a magnetic field around the conductor. Such a current will cause the deflection of a magnetic needle.

century. As a simple experiment, it was most important for several reasons.

*a*) It shows that there must be a magnetic field set up around a conductor which carries an electric current.

*b*) It enables one to tell in what direction the current is flowing in a conductor, because reversing the direction of the flow of current reverses the direction in which the north-seeking pole of the compass needle is deflected. [See Fig. 15–2.]

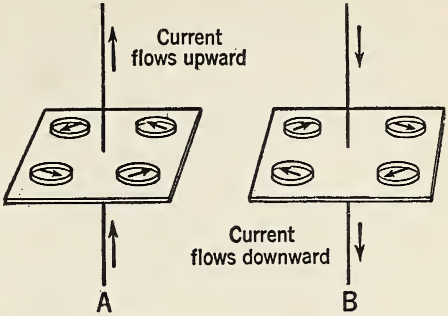
Fig. 15–2. When the current flows from south to north, the north-seeking pole is deflected toward the west. Reversing the direction of the current reverses the direction in which the needle is deflected.




*c*) It led to the invention of the *electromagnet*, which has many uses. It also led to the invention of certain electrical measuring instruments.

If we examine Figure 15–3, we can see how the needles

Fig. 15–3. Tiny compasses may be used to show that there is a magnetic field encircling a wire carrying an electric current.




of small compasses tend to set themselves at right angles to the lines of force which encircle a vertical conductor through which a current is flowing. This, too, is a simple experiment that can be easily demonstrated in the classroom.

**315. What happens when we pass a current through a coil of wire?** If we bend a bar magnet into a horseshoe shape, we make of it a stronger magnet because the two poles

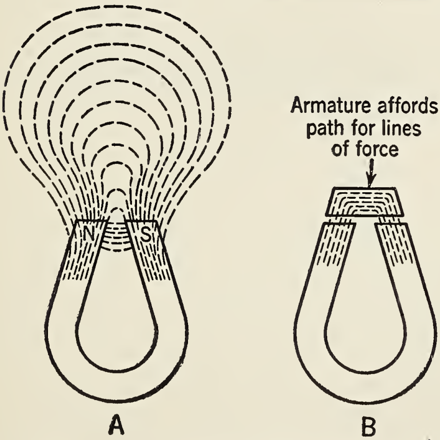



Fig. 15–4. When a piece of soft iron called an *armature* is used, most of the lines of force pass through the iron armature. When the magnet is to be used, the armature must be removed. The dotted lines show the lines of force in the magnetic field.

are brought closer together. [See Fig. 15–4.] If we pass an electric current through a single loop of wire, that loop will act like a magnet. We may use a compass needle to show that the loop has polarity. [See Fig. 15–5.] Let us take a piece of insulated wire and wind 15 or 20 turns of it around

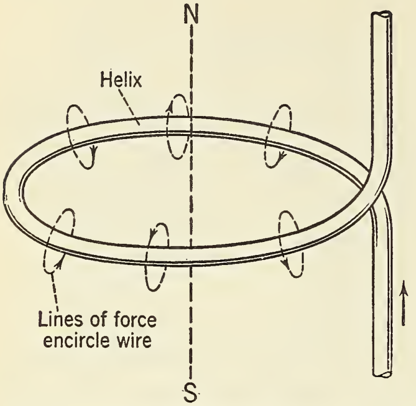
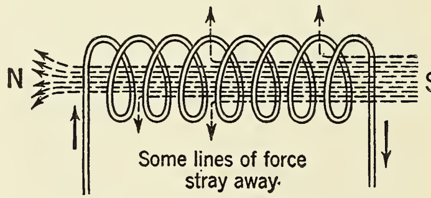



FIG. 15–5. A single loop of wire acts like a disc-shaped magnet. Each face of the loop will show polarity. Note the manner in which the lines of force encircle the wire in the loop.

a lead pencil to make a coil, or a spiral called a *helix*. [See Fig. 15–6.] If we connect the ends of the coil to a push button and a dry cell, we find that such a coil really becomes a magnet when the current flows through it. If we hold one end

FIG. 15–6. Several loops of wire form what is called a helix. Such a loop has polarity and shows rather feeble magnetic properties.




of the coil near a magnetic needle, we find that it attracts one pole of the needle and repels the other pole. We find, too, that its lines of force seem to be concentrated near the ends of the coil, just as they are in a bar magnet. The coil loses its magnetism, however, just as soon as we break the circuit.

316. **How can we make an electromagnet?** Let us try to see whether the coil we used in the preceding section will pick up any carpet tacks when we hold one end near the tacks and then close the circuit. It is doubtful if it will be strong enough to do so. Next let us put a soft iron rod, about the length of the coil and of slightly smaller diameter, inside the helix. [See Fig. 15–7.] Let us try again to pick up

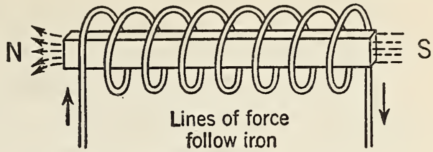



FIG. 15–7. The addition of an iron core to a helix converts it into an electromagnet.

some carpet tacks when the iron core is inside the coil. If your dry cell is a good one, you will probably find that several tacks will be picked up and they will cling to the coil and core as long as the electric circuit is closed. If we open the circuit, they will fall off easily. (The north-seeking pole of an electromagnet will repel the north-seeking pole of a compass needle, and attract the south-seeking pole.)

**317. How does an electromagnet behave?** The commercial magnet is made by winding many turns of insulated wire around a core of soft iron. If it is to be a horseshoe-shaped magnet, one coil of wire is wound around one end of the core in a clockwise direction, and another coil is wound around the other end of the core in a counterclockwise direction. One coil then forms the north-seeking pole of the magnet and the other coil forms the south-seeking pole. It remains a magnet so long as the current flows through its coils, but it loses nearly all its magnetism when the circuit is broken.

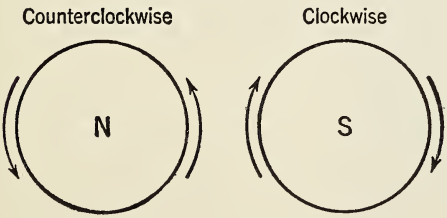



FIG. 15–8. If one looks toward the north-seeking pole of a horseshoe-shaped electromagnet, he finds the current flowing counterclockwise. It flows clockwise around the southseeking pole.

For these reasons it has an advantage over the permanent magnets discussed in Chapter 13. [See Fig. 15–8.]

**318. Upon what does the strength of an electromagnet depend?** The electromagnet has another advantage over the permanent magnet. Its strength can be varied almost at will.

In fact, there are three factors upon which the strength of an electromagnet depends.

*a*) As more and more turns of insulated wire are wound upon the core, the magnet becomes stronger and stronger.

*b*) The easiest way to increase the strength of an electromagnet is to increase the amount of current flowing through the magnet. If we wish a weaker magnet, we pass less current through the magnetic coils.

*c*) The use of a soft iron core increases the strength of the magnet.

**319. How is the electromagnet used?** It is generally considered that an American physicist, Joseph Henry, really invented the electromagnet. [See Fig. 15–9.] It is a marvelous device, because we can vary its strength at will, and because we can make it a magnet one moment and have it lose almost all its magnetism the next moment. Then, too, while the ordinary permanent magnet can lift at most only a few ounces, the electromagnet can be made so strong that it

FIG. 15–9. Joseph Henry (1797–1878) was an American physicist. As secretary of the Smithsonian Institution, he founded the Weather Bureau. He developed the electromagnet. He is the inventor of the telegraphic principle and of the relay.

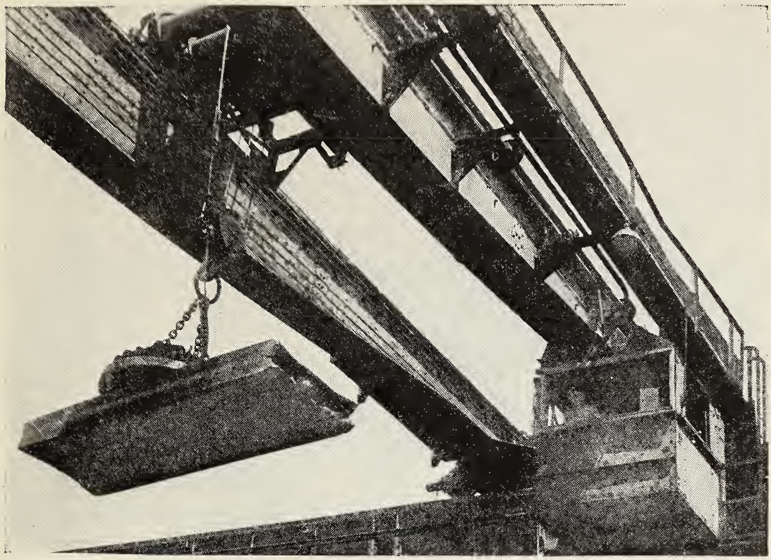


FIG. 15–10. The lifting magnet is used extensively around steel plants, for lifting steel bars or scrap steel or iron. Do you think such a magnet can pick up a keg of nails? (*Courtesy U. S. Steel Corp.*)

will lift 200 pounds for every square inch of area in the faces of its poles. Its uses are many and varied.

*a*) *The lifting magnet.* Around a steel plant, there are many *billets* of steel to be loaded and unloaded from freight cars. A large lifting magnet is lowered by a crane to a pile of billets. Then the current is turned on, and the crane lifts the magnet with its load of steel billets and swings it over the top of a car. Then the circuit is broken, and the load is released and falls into the car. Old iron and scrap iron are handled in the same manner. [See Fig. 15–10.]

When such lifting magnets first came into use, workmen were afraid to work near or under them, but it was soon found that the danger of dropping a piece of steel from such a magnet is far less than it had been before when grappling hooks were in use.

*b*) *In motors and dynamos.* In the next chapter we shall learn something of how a dynamo makes electricity. Nearly

all electricity for commercial purposes is made by a dynamo, and the dynamo uses an electromagnet in generating an electric current.

One finds the electric motor, too, in common use everywhere. When we study the motor more carefully, we shall learn that it is really made up of two electromagnets.

*c*) *In instruments for measuring.* Many *voltmeters* and *ammeters* which are used for measuring voltage or amperage use a permanent magnet and an electromagnet. The electromagnet is mounted on a pivot so that it will be free to swing through an arc between the poles of a permanent magnet, which is horseshoe-shaped. [See Fig. 15–4.] If we permit current to flow through the pivoted electromagnet, it will be magnetized and have two poles. The poles are mutually attracted and repelled by the poles of the permanent magnet, which is mounted on the board of the instrument. The movable magnet carries a pointer which moves over a graduated scale. The stronger the current passed through the instrument, the greater the deflection of the pointer. The voltmeter is graduated to read volts directly. The ammeter is graduated to read amperes directly.

*d*) *In the electric bell.* The electromagnet finds use in signaling devices. The telegraph and telephone are discussed in a later chapter. If we are to understand how an electric bell operates, we shall need to refer to Figure 15–11.

Attached to the iron base of the bell we have two binding posts, B and D. The post B is connected directly with the base of the bell, but an insulated wire is connected directly with D beneath the base of the bell. The post D is insulated from the iron base of the bell. The wire from D runs to the magnet, is wound around the core, and then passes down under the bell again to the contact screw.

Let us trace the current through the bell. Starting at D, the current flows to the electromagnet, then down through the base of the bell to the contact screw, and then along the flexible spring to which a piece of soft iron called the *arma-*

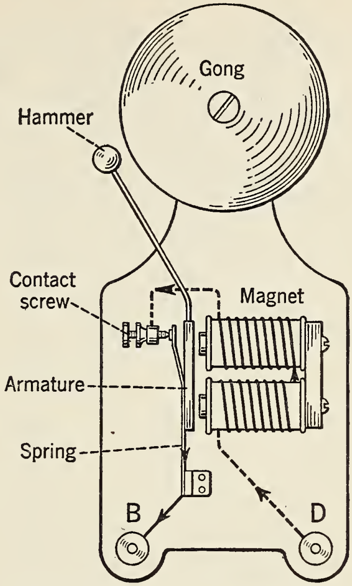



FIG. 15–11. The electric bell uses an electromagnet for moving the hammer to and fro. When the current is on, the armature moves toward the right, and the hammer strikes the gong. When the current is broken, the spring pushes the armature toward the left until it touches the contact screw, and again closes the circuit. As the current is first made and then broken, the bell continues to ring.

*ture* is attached, and then to the other binding post B. The flexible spring carries an iron armature which may vibrate back and forth in front of the poles of the electromagnet. The armature carries a hammer which strikes the gong as the armature swings toward the magnetic poles.

What makes the bell ring? When the current flows through the coils of the magnet, it magnetizes them, and the armature is pulled sharply toward them. It carries with it the hammer which strikes the gong. But as the armature moves over toward the magnet, it pulls the spring away from the contact screw and breaks the circuit. The coils lose their magnetism. Then the flexible spring swings back and the bent end once more makes contact with the contact screw. The current begins to flow once more, and the same operation is repeated over and over again. The coils are magnetized and then lose their magnetism. The circuit is made and then broken. The armature vibrates back and forth between the poles of the magnet and the contact screw. One bell may

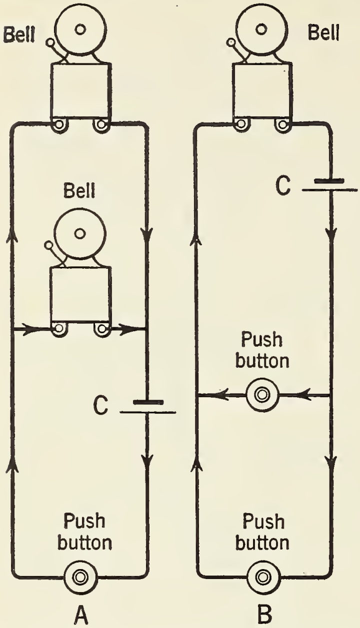



FIG. 15–12. It is possible to have two bells, both of which are operated by one battery and one push button. It is possible, too, to have one bell which may be operated with one battery and either one or two push buttons. For example, a push button at your back door may ring the bell, or a push button under your dining room table may be used to close the bell circuit.

be rung by two or more different push buttons, and two or more bells may be rung by a single push button. [See Fig. 15–12.]

**320. Some interesting changes in energy.** In the voltaic cell, chemical energy is used up as the solution attacks the negative plate. Electrical energy is produced. Hence, it is correct to say that a voltaic cell is a device used to change chemical energy into electrical energy. There is a common saying: "It is a poor rule that will not work both ways." That seems to be true in this case, too, for it is possible to use electrical energy to do chemical work.

Men use electrical energy to take metals from their ores, to plate one metal with another metal, to make electrotypes from which books and advertisements may be printed, and to charge storage batteries, which are such a necessary part of the modern automobile. In all these cases, electricity is used to *decompose* chemical compounds, or to *separate* the different parts of a compound from one another in solution.

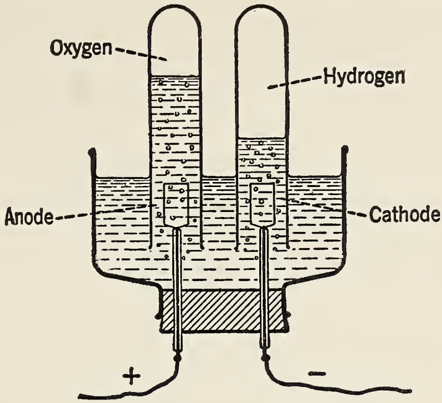



FIG. 15–13. Such an electrolytic cell may be used if we wish to decompose water by means of the electric current. Hydrogen is set free at the *cathode,* and oxygen is liberated at the *anode.*

**321. What is meant by electrolysis?** Suppose we set up the apparatus shown in Figure 15–13. The bottle is filled with water to which a little sulfuric acid has been added to make the water a conductor of electricity. Pure water is a poor conductor. The wire *terminals,* or ends, of the apparatus are connected to at least two dry cells joined in series in order to furnish about 3 volts of electrical pressure.

As the current flows, the water, which we know is composed of hydrogen and oxygen, is decomposed by the current. The hydrogen collects in one test tube and the oxygen in the other. The volume of hydrogen collected is just double the volume of oxygen that is collected, proving that water is composed of two volumes of hydrogen to one volume of oxygen. Such decomposition of a compound by means of the electric current is called *electrolysis.*

**322. What are the parts of an electrolytic cell?** Any cell in which electrolysis occurs is called an *electrolytic cell.* It is sometimes called a *secondary cell.* The solution used in such a cell is called the *electrolyte.* The two terminals, or plates, of the electrolytic cell are called *electrodes.* [See Fig. 15–14.] For decomposing water, the electrodes used are made of carbon or platinum, two elements that are not attacked by either the acid solution or the gases that are set free.

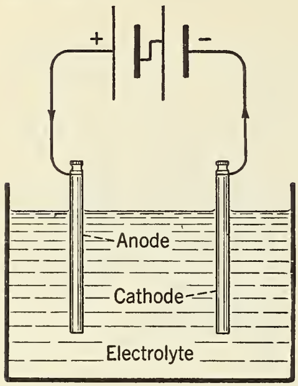



Fig. 15–14. Such a cell may be used for work in electrolysis. The current enters the cell by way of the anode and leaves by way of the cathode. The electrolyte is usually some acid, base, or salt in solution.

The electrode which is attached to the positive terminal of the dry cells is called the *anode*. The word comes to our language from the Greek word which means *the way up into*. In the electrolysis of water, the oxygen collects at the anode. The electrode which is joined to the negative plate of the dry cells is called the *cathode*. This word also comes from the Greek, and means about the same as our English words *the way down and out of*. The hydrogen gas always collects at the cathode.

**323. How is it possible to plate one metal with another?** Suppose we have some table forks that we wish to plate with silver. We use an electrolytic cell. Into the cell we pour a solution containing some compound of silver, generally silver cyanide. For the anode we use a bar of pure silver. We attach the forks to the cathode, in such a manner that they will be entirely submerged in the solution of the salt of silver. The cell is then connected with the source of current, which may be cells in series.

As the current flows, the silver compound is decomposed. The silver that is formed then migrates to the cathode, where it is deposited in a smooth, even coat all over the surfaces of the forks. In the meantime, silver is dissolving at the anode to keep the solution supplied with silver. Thus the process goes on continuously until the circuit is broken.

In order to have the silver deposited evenly upon the forks, a rather low amperage must be used. The amount of silver that will be deposited and the thickness of the plate or coat will depend upon the length of time the current flows and also upon the strength of the current. For example, a current that flows for 30 minutes will deposit just twice as much silver as the same current flowing for only 15 minutes. Two amperes of current deposit silver just twice as fast as a current of one ampere does.

If we wish to plate an object with copper, we use for the anode a bar of pure copper. For the electrolyte, we use some compound of copper in solution, such as blue vitriol, or copper sulfate. Almost without exception, *the object to be plated is used as the cathode.* The following general rule may be used for plating with a metal: for the anode use a bar of that metal with which the object is to be plated; for the cathode, use the object to be plated; for the electrolyte, use a solution containing some salt of the metal with which the object is to be plated. For gold plating, the cyanide of gold is used; for nickel plating, a solution of a double salt of nickel is used.

**324. How is plating used in making books?** In manufacturing a book of which the publishers expect to make successive printings, the type is first set up on either a *monotype* or a *linotype* machine. A monotype machine sets each character of type separately. A linotype machine sets whole lines of type in a solid strip. Proofs are taken, and corrections are then made. The type is made up into pages, and the pages tied up so that the type does not fall out of place. Then an *electrotype* is made for each page.

First a kind of special wax is hammered down upon the type page. The wax fits into the depressions around the type and it is indented by the projections of the type. This wax layer is then removed, and that surface of it that was next to the type is covered with a layer of *graphite* to make it a conductor of electricity. This graphite-covered sheet of wax

is then attached to the cathode of a copper-plating cell. As the copper is plated upon the wax, its surface will be exactly like that of the type page, but *it will have the advantage of being in one piece.* This copper electrotype is then backed with a cheaper metal until it is thick enough so that it will not bend in the printing press. An electrotype is made for each page of the book. The electrotypes are sometimes hardened by being plated with a thin layer of nickel. Thousands of copies can be printed from such electrotypes. [See Fig. 15–15.]

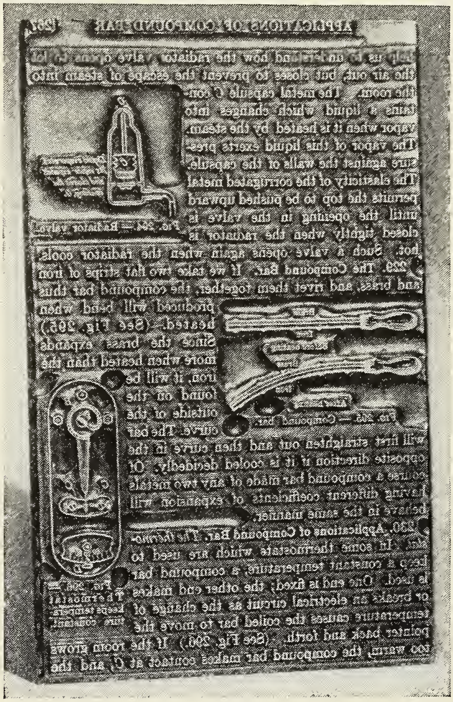


Fig. 15–15. Many books are printed from electrotypes, because it is possible to produce thousands of copies from such an electrotype. After the type is set for an advertisement, several electrotypes may be made and sent to magazines all over the country. As you would expect, both the type and the illustrations of this electrotype are in reverse, just as when you hold a book up before a mirror. Can you explain why this is so?

Of course publishers can never be sure how many copies of a book they will sell. Possibly 10,000 copies are printed for a first printing, or for what is sometimes called a first edition. Then the electrotypes are stored away for future use. When a second printing is needed, it is a simple mat-

ter to place the electrotypes in the press, and print as many additional copies as are necessary.

If an advertisement is to appear in a number of magazines, the type for it may be set, and an electrotype made to send to each magazine. The magazine publishers then hold that electrotype in order to print the advertisement in as many different issues as are ordered.

Electrotypes are used also for making a large number of copies of metal designs and phonograph records. One master phonograph record is made by an artist or by an orchestra, and from that master record an electrotype is made. Thousands of copies of that record can then be made from the electrotype by pressing it into the wax material used for making phonograph records.

**325. Of what does the storage battery consist?** The simplest possible storage cell in a storage battery consists of two lead plates that are immersed in a solution of sulfuric acid in water. In a commercial cell, there may be from 13 to 17 or more lead plates in each glass jar. In the voltaic cell, we start with *two unlike plates,* and we get electrical energy from the cell at the sacrifice of chemical energy. Such a cell is called a *primary cell.* In the storage cell, we start with *two like plates,* and we use electrical energy to make them unlike. Such a cell is often called a *secondary cell.* After it has been charged by making the plates unlike, it then behaves much like the voltaic cell and can furnish an electric current.

**326. What is stored in a storage cell?** When an electric current is passed through a simple storage cell consisting of two lead plates immersed in sulfuric acid, the water decomposes in the manner described in section 321. Hydrogen gas escapes at the cathode. The oxygen, which is set free at the anode, does not escape. It unites with the lead plate which forms the anode and changes it into a plate which is now covered with a reddish-brown coating of lead peroxide. This operation is called *charging* the cell. *Chemical energy has been stored up in the cell.*

The two unlike plates formed by the charging of the storage cell will now act like a voltaic cell. We may now use its stored-up chemical energy to produce an electric current. As we do so, we are *discharging* the cell. The hydrogen that is set free by such discharging unites with the oxygen stored up in the lead peroxide and changes it back to lead again. When all the oxygen is used up, the cell is entirely discharged. We now have two lead plates which are alike, and we cannot get any more current from them.

The great advantage of the storage cell, however, lies in the fact that it can be charged again and again. We merely pass an electric current through the cell to form more peroxide. Then the cell can furnish current until it becomes discharged. In your automobile battery, a generator driven by the engine is charging your storage battery while you are driving.

**327. For what purposes is the storage cell used?** The storage battery is used to supply current for use on telephone circuits. It is used for lighting railway trains. It may be used to supply power to run light trucks, and for delivery of

FIG. 15–16. Light trucks to deliver groceries are often powered by a gasoline engine using a storage battery. (*Philip D. Gendreau*)

baked goods, laundry, or milk. Storage batteries often find use in lighting farm homes that are not near electric power lines. [See Fig. 15–16.]

In the automobile, the storage battery supplies current for many things: the lights, the horn, the self-starter, the spark plugs, the radio, and the motor for the car heater.

**328. How to care for a storage battery.** A storage battery that is properly cared for will last for years. It is injured if it is permitted to become completely discharged, or if it stands for some time when not charged. It can be injured by charging it too rapidly, or by discharging it at too rapid a rate. Freezing injures a battery, but it will not freeze if fully charged unless the temperature falls far below zero. Distilled water must be added to the battery from time to time to replace the water that is lost by evaporation.

A small instrument called a *hydrometer* is used to test the battery. When a battery is being charged, water is decomposed and used up, and the density of the battery fluid rises. The hydrometer shows a reading of about 1.300 when the battery is fully charged. That means that the fluid is 1.3 times as dense as water.

As the battery is being discharged, water is being formed, and the density of the fluid decreases. It may fall as low as 1.15, but a battery should be recharged before the density of the electrolyte falls that low.

**329. How do we get heat from electricity?** As you sit and look at the coils of a bread toaster, heated red hot by the electric current, do you ever wonder why the cable leading to the toaster does not get hot, too? As a matter of fact it does get warm, but the amount of heat produced in the cable is not great enough to raise its temperature very much. How do we explain it?

We may try the following experiment. We connect the two binding posts of the apparatus of Figure 15–17 with a dry cell. The two posts are joined by two short pieces of No. 30 copper wire, which are connected by a short piece of

German-silver wire of the same diameter. When the circuit is closed, the German-silver wire will probably get red hot and it may melt. The copper wires do not get hot enough to glow. The German-silver wire probably has at least 15 times as much resistance as the copper wire. The resistance is so great that much of the electrical energy is changed to heat energy. In the case of the toaster, the coils are made of *nichrome* wire, which has more than 60 times as much resistance as copper wires of the same diameter. The heat is concentrated at those points in an electrical circuit where the resistance is greatest. The filament of an electric-lamp bulb is another example.

We may use a little larger copper wire to join the two binding posts of the apparatus of Figure 15–17. One dry cell

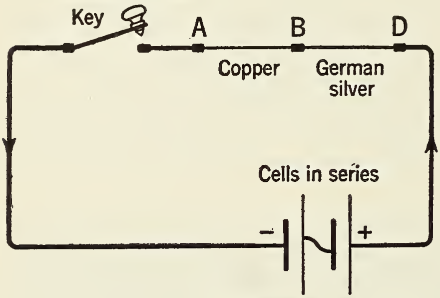



FIG. 15–17. The German-silver wire and the copper wire have the same diameters. The German-silver wire gets much hotter because it has many times as much resistance as copper.

may not furnish enough current to melt that copper wire. If we put two or three dry cells in series, the current will probably be increased enough to melt the wire. It is possible to show by experiment that the heating effect of an electric current does the following.

*a*) It increases with the resistance that is offered to the flow of the current.

*b*) It increases as the current in amperes is increased. A current of two amperes flowing in a circuit will produce *four* times the amount of heat that a current of one ampere will produce in that circuit.

*c*) It increases with the time that the current flows. Ten

Fig. 15–18. In this picture you will see two electrical appliances for use in the home. Can you imagine housekeeping in the days before all our labor-saving devices came into use? Would you have liked to have lived then, and in the manner of the early settlers? (*Courtesy Westinghouse*)

times as much heat will be developed in ten minutes as is produced in one minute.

**330. What heating appliances are in use?** You are familiar with the bread toaster, the coffee percolator, the electric flatiron, the electric waffle iron, the portable heater, the hair curler and drier, and the electric hot pad as examples of appliances heated by means of the electric current. [See Fig. 15–18.] The electric grill is common in localities where elec-

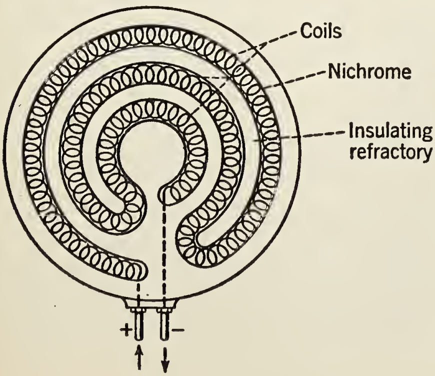



Fig. 15–19. This diagram shows an important use for the high resistance wire called nichrome. It gets very hot when current flows through the coils.

trical energy is inexpensive. No doubt you can add to the list given here. [See Fig. 15–19.]

The preparation of *nichrome* affords an interesting example of the methods used by scientists. No single metal is known whose properties make it suitable for the heating coils of electrical appliances. Hence scientists decided to try to make an alloy that has suitable properties. They made nichrome, an alloy of nickel and chromium. Nichrome does not tarnish. It does not oxidize easily. It has a very high electrical resistance. It has a high melting point.

**331. What is meant by an overload?** As the tributaries of a river continue to pour water into the river during a flood, the river may become overloaded. Then it breaks over its banks and becomes destructive. It may carry away buildings.

In a similar manner, the electric wires in your house can carry safely a certain number of amperes. Let us use 17 amperes as an example. If you try to force them to carry more than that number of amperes, then you have an *overload.* The wires may melt and set fire to your house.

**332. How is an overload caused?** One cause for an overload is the use of too many appliances on one circuit. The washing machine in the laundry may be using 4 amperes of current. A coffee percolator is taking 6 amperes. A waffle iron is using 6 amperes. Someone turns on the radio, which possibly takes one ampere, and two or three lights which take a half-ampere each. Then we have the wires overloaded and attempting to carry 18 amperes or more of current, when their capacity is only 17 amperes.

An overload may also be caused by a *short circuit.* The cord of a floor lamp is bent and twisted, and possibly trod upon, until the insulation is worn away. Then the two bare wires touch one another. That causes a short circuit. The resistance falls almost to zero, and the number of amperes jumps up correspondingly. Instantly there is an overload on the circuit.

**333. How can protection be secured by proper wiring?** If a copper wire melts on account of an accidental overload, it may set fire to any flammable material that is near it. Its melting point is higher than the kindling temperature of wood. As a protection against fire, the electric wires leading to the various rooms are enclosed in a spiral metal tube. But if an overload should occur, the wires might melt at any point. It might be in the ceiling of the living room, or in the walls of the kitchen. To reach the melted wires to repair them would necessitate tearing away the plastering or ripping up the flooring. Either one would be a nuisance and an expense. For that reason, fuses are used to make the wires melt at a convenient place, provided an overload does occur.

*Fuses* are generally installed in a metal box in the basement. Each fuse is made of an alloy which has a low melting point. The fuse, too, must have a lower carrying capacity than the wires in the walls of the house. For example, if the wires can carry 17 amperes safely, a 15-ampere fuse may be used in the fuse-box. Then when an overload does occur, the fuse melts and breaks the circuit before the wires themselves get hot enough to melt. All that is necessary, now, is to remove the cause of the overload, and to install a new fuse. The new fuse costs only a few cents, and the time needed to replace it is not more than a couple of minutes. Some persons *foolishly* put a penny in the socket instead of replacing the burnt-out fuse. Such practice is foolish because it removes the very thing that was placed there for your protection. Even if your house did not burn as a result of such careless practice, it might mean an expensive repair bill. If your house should burn, you would find it difficult to collect any fire insurance. It is best to have a spare fuse handy to replace one that may melt, or blow.

**334. How does electricity produce light?** In our study of home lighting, we learned something about the electric-light bulb. If we heat a stove poker hot enough, it begins to glow. In the electric lamp, the filament has so much resist-

ance that the electric current flowing through it will heat it white hot. This is known as heating to *incandescence.* Unfortunately, much more of the electrical energy is transformed into heat energy than is changed into light energy.

Possibly at some future time scientists may be able to make "cold" light, as the fireflies and the glowworms do. The neon vapor lamps are much more economical than the filament lamps are. In fact, they cost so little to operate that advertisers do not always trouble to turn them off even in daylight. Sodium vapor lamps and mercury vapor lamps are coming into use for highway lighting.

**335. Many different kinds of bulbs are in use.** For use in dwellings, bulbs are usually made to operate on a circuit whose voltage is from 110 to 120. They can be made, however, to operate on almost any voltage. For example, the flashlight bulb for use with a single dry cell takes only 1.5 volts. A flashlight equipped with two dry cells needs a 3-volt bulb.

For automobile headlights, a 6-volt bulb is required. The storage battery in a car usually consists of three separate cells, joined in series. Each storage cell, when fully charged, furnishes about 2.2 volts. The maximum voltage of the three cells is 6.6.

Some of the bulbs now sold for use on Christmas trees can be used on a 120-volt circuit. Many of the older ones, however, are 14-volt bulbs, all wired in series.

**336. How do we buy electricity?** *The watt is the unit of electrical power. The number of watts is found by multiplying the number of volts pressure by the number of amperes flowing through the circuit.* For example, a flatiron operates on a 120-volt circuit. It uses 5 amperes of current. That flatiron is using electrical power at the rate of 600 watts ($120 \times 5 = 600$).

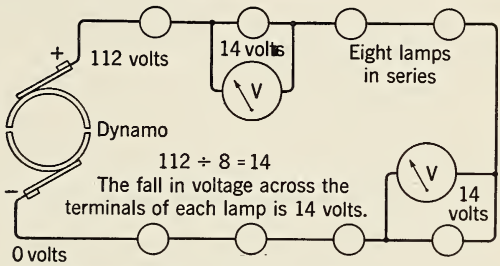
Suppose that the current flows through the flatiron continuously for one hour. The amount of energy it uses is 600 *watt-hours.* The *kilowatt-hour* is equal to 1000 watt-hours.

Electricity is nearly always sold at a certain price per kilowatt-hour. The price varies in different localities, from as low as 2¢ per kilowatt-hour in one city to 12¢ or more in other places. The kilowatt-hour actually means that you receive 1000 watts of electricity for a total period of one hour.

An electric bill is not difficult to calculate. Suppose that the flatiron mentioned above is used for five hours. That means a consumption of 3000 watt-hours ($120 \times 5 \times 5$) of electrical energy. That equals 3 kilowatt-hours. Suppose the cost of electrical energy is 8¢ per kilowatt-hour. Then the cost of operating the flatiron for five hours is exactly 24¢. At the same rate, one can operate forty 25-watt lamps one hour for 8¢. ($40 \times 25 = 1000$ watts.)

**337. What is series wiring?** In our study of the voltaic cell, we learned that such cells may be joined in series. It is possible to have some electrical appliances wired in series, too. Small bulbs for Christmas tree lighting are often wired

FIG. 15–20. Turning off one lamp in a series-wired circuit will cause all lamps to go out.




in series. Figure 15–20 shows such an arrangement. This type of wiring has its disadvantages.

*a*) All the appliances receive the same amount of current. It would be impossible, for example, to have a flatiron receive 5 amperes of current, a toaster 6 amperes, and a 100-watt bulb one ampere if they were all wired in series.

*b*) This type of wiring increases the total resistance in a circuit very decidedly. Each conductor and each appliance adds its resistance to that of every other one in the circuit.

*c*) If one appliance burns out, or is turned off, the circuit is broken and all are off. You have doubtless had such an experience with electric bulbs *wired in series* for lighting a Christmas tree.

338. What is parallel wiring? If there were a single road between Detroit and Chicago, all the traffic would pass along that road, and there would be much congestion. If there were two parallel roads, of equal width, half of the traffic would normally pass over each road. The congestion would be much less than for the single road.

In a similar manner, it is possible to have two wires parallel to each other. [See Fig. 15–21.] Then the electric current will divide, and a part of it will flow through each wire. Either branch of the circuit is said to be a *shunt* to the other branch. Houses are wired in parallel, as shown in Figure 15–22. Such wiring has several advantages, two of which are given below.

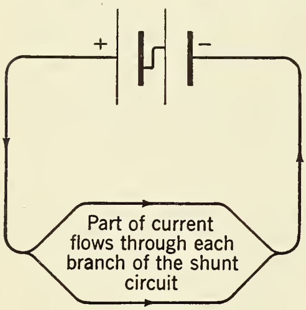



FIG. 15–21. Just as it is possible to have parallel roads in order to carry more traffic, so it is possible to have part of the electric current flow through one branch of a divided circuit and the remainder through the other branch.

*a*) Turning off one of the appliances does not affect the

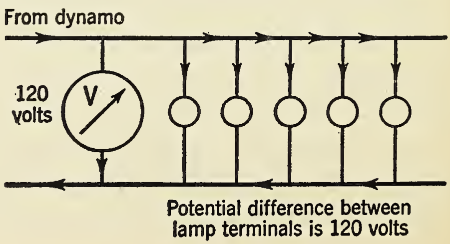



FIG. 15–22. The lamps in a lighting circuit are wired in parallel. Other appliances are also wired in parallel.

others. If houses were wired in series, we should have to turn on all the lights at one time.

*b*) Just as it is possible to have one of two parallel roads wider than the other one and thus be able to accommodate more traffic, so it is possible to have a different amount of current flow in any branch of a circuit wired in parallel. For example, we may have a percolator which takes 5 amperes plugged into one socket, and a vacuum cleaner which takes only 2 amperes plugged into another socket.

**339. How does electricity affect plants and animals?** We have seen that the electric current set up by Galvani's scalpel and the copper wire fastened to the frog's leg stimulated the frog's nerves and caused its leg to twitch. You are conscious of a muscular contraction when someone shuffles across a rug and then touches your finger.

Small quantities of electricity seem to be beneficial for certain diseases. Doctors sometimes recommend the use of electricity for treating certain ailments.

The question is sometimes asked, "How much voltage does it take to kill a person?" There is no answer to that question, because persons differ in their susceptibility to electrical shock and the conditions vary too. If you are standing on a rug, and your hands are dry, you probably will not feel more than a prickling sensation if you touch a bare wire on a 120-volt circuit. On the other hand, if you are standing barefooted in a bathtub, which is connected with the ground through metal pipes, and your hands are wet, 120 volts will give you a severe shock. Under such conditions, it becomes dangerous, and it may prove fatal. Even more dangerous are 220 volts, which produce a bad burn, and possibly a fatal shock. One must be very careful not to touch bare wires that carry an electric current.

If electric wires are strung underground, and an electric current is passed through the wires, the plants growing there seem to be stimulated. Gardeners have sometimes used such a method to make vegetables mature more quickly.

## *Questions*

1. How would you proceed to show that there is a magnetic field around a wire carrying a current?
2. A coil of wire carrying a current is suspended so it is free to swing around into any position. What direction will it take?
3. How would you make an electromagnet?
4. Upon what factors does the strength of an electromagnet depend?
5. How would you proceed to find which is the north-seeking pole of an electromagnet?
6. What is the purpose of the armature of an electric bell?
7. If you have two push buttons for one electric bell, would you connect them in series or parallel? If possible, try the experiment.
8. Is it possible to have two electric bells on one circuit, operated by one battery and one push button? How would you wire them?
9. In electroplating, what substance is used for the anode?
10. In electroplating, what is used as the cathode?
11. If you were planning to use the same advertisement in 40 different papers, what advantage would there be in having 40 electrotypes made to send to the different papers?
12. What is actually stored in a storage cell?
13. Make a list of as many uses for a storage battery as you can.
14. By using a hydrometer, a man finds that the electrolyte in his storage battery is 1.2 times as dense as water. What should he do?
15. How does the development of the alloy known as nichrome show the results of applying the scientific method?
16. In what ways may an overload be produced on an electric circuit?
17. Why may an overload be dangerous? What protection is in common use against the danger from overloads?
18. Why is it dangerous to put a penny in the socket of a blown-out fuse?

19. Is a fire insurance company justified in refusing to pay insurance on a building that has burned, if a penny is found in one of the fuse sockets? Give a reason for your answer.

20. Why are neon lamps used so largely for advertising purposes?

21. What are the advantages of parallel wiring in a house lighting circuit?

22. One sometimes sees the sign, "Danger! High voltage." Why are such signs in rather common use?

23. Is it safe to replace a 15-ampere fuse plug with one of 30-amperes capacity? Give a reason for your answer.

24. Have you ever seen men welding metals by the use of the electric current? If so, what does this practice show about the heating effects of the electric current?

## *Some things for you to do*

1. Make an electromagnet by winding some No. 22 insulated wire on an iron rod about three inches long and a quarter of an inch in diameter. Slip some rubber bands on each end to hold the wire in place. It may then be shellacked to make the magnet more permanent. Connect the terminals with a voltaic cell and test for magnetism.

2. Try to plate with copper by immersing two carbon rods in a jar containing some copper sulfate solution. At least two dry cells must be connected in series to plate properly.

3. Read your electric meter two or three times a week for two weeks. Calculate the cost of current used during the two-week period.

4. To a block of wood about one inch square and long enough to rest upon the opposite sides of a battery jar, tack, on opposite sides, two sheets of lead, each about 4 inches square. Fasten wires to the upper edge of the lead sheets so they can be attached to a source of current. Connect the wires with two or more dry cells in series for a few minutes. Have you stored up enough energy to ring a bell?

## THINK ABOUT THESE!

1. How many dry cells would it take to furnish 15 volts, if they were joined in series?
2. Is it correct to say that a dynamo creates electrical energy?
3. Can you make a list of six things that an electric motor can do?

## WORDS FOR THIS CHAPTER

**Armature.** As used in this chapter, the part of a dynamo whose coils cut the lines of force of the field magnet.

**Alternating current.** Electrical current which flows for a fraction of a second in one direction, and then for an equal fraction flows in the other direction.

**Direct current.** Electrical current which flows in only one direction.

**Commutator.** A device which changes alternating current into direct current.

**Dynamo.** An electrical generator with a commutator.

**Transformer.** A device used to raise or lower the voltage of an alternating current.

CHAPTER 16 ______________ UNIT 7

# How Do We Use Generators and Motors?

**340. Who was Michael Faraday?** We are not far wrong when we say that the story of commercial electricity is the story of Michael Faraday. If one were to call the roll of men of science of all time and in all countries, he would find Faraday's name among the leading ten. Faraday, the boy, was apprenticed to a bookbinder, but he had no liking for that work. At the age of twenty-one, he had the privilege of hearing the great scientist Sir Humphry Davy give a series of lectures. He was so fascinated that he begged Davy to permit him to work in his laboratory. [See Fig. 16–1.]

Faraday later learned how to liquefy gases. He made many new compounds in the field of chemistry. He studied electrolysis, and worked out the laws governing the amount of metal that is deposited from an electroplating solution. He made studies in the field of light, too, but his most important discovery is the one that makes it possible for the world to have electricity for commercial purposes. Sir

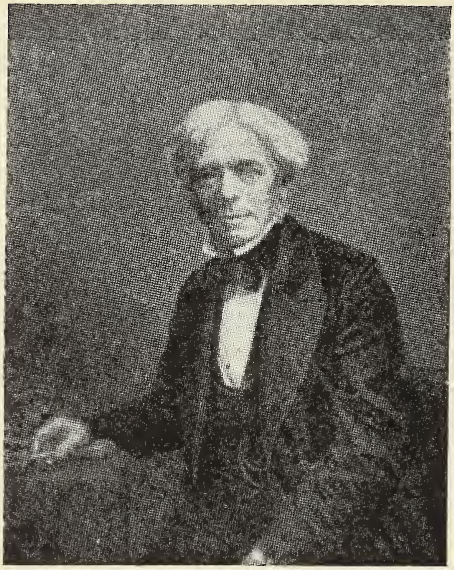


FIG. 16–1. Michael Faraday (1791–1867) was a distinguished English physicist and chemist. He was assistant to Sir Humphry Davy at the Royal Institution. Faraday liquefied certain gases and discovered the principle of electromagnetic induction which led to the development of the dynamo.

Humphry Davy was asked at one time what he considered his greatest discovery. His reply was: " Michael Faraday."

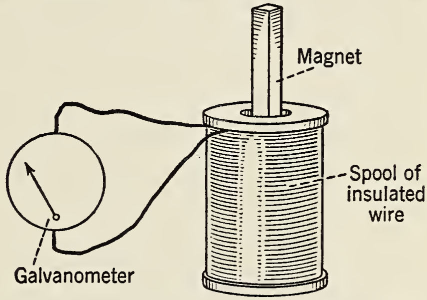
**341. How is electricity produced?** In our study of the dry cell we learned that it requires a very large number of dry cells to furnish sufficient voltage to operate lights or other electrical appliances. Of course we have the storage cell, but it takes electricity to charge such a cell, and it is not possible to get more than 75 per cent as much energy from a storage cell as one uses to charge the cell.

The big problem, then, was to find some better method of producing electricity on a large scale. The answer to that problem came in the early part of the nineteenth century as a result of some very fruitful experiments by Michael Faraday.

You remember that Oersted showed that *a current flowing through a conductor sets up a magnetic field around that conductor.* Since the relationship between magnetism and electricity is that close, it occurred to Faraday to try to see whether *a magnet can be used to set up an electric current.*

He took a spool of insulated wire and fastened the terminals of the wire to a *galvanometer,* which is an instrument used to detect the presence of an electric current. Then he thrust a bar magnet down into the spool of wire. [See Fig. 16–2.] The needle of the galvanometer was deflected, show-

FIG. 16–2. The needle of the galvanometer is deflected when the magnet is thrust down into the coil or when it is withdrawn from the coil.




ing that a current was actually induced, or led into the wire, by the moving magnet. He found that a current was set up in the opposite direction when he withdrew the magnet.

Then Faraday tried holding the magnet still and moving the spool or coil of wire. He found that it does not matter which one is in motion, but that it is necessary for one of them to be in motion. His discovery may be expressed by the following statement: *Voltage is always set up in a conductor when it moves through a magnetic field in such a manner that it intersects, or cuts across, the lines of force of that field.* It is called an *induced voltage.* If the circuit is closed, an *induced current* is also set up in such manner. [See Fig. 16–3.]

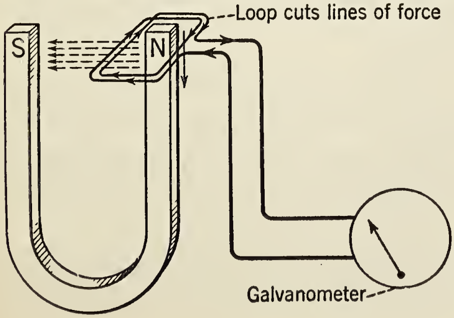



FIG. 16–3. Moving the loop of wire down over the pole of the magnet sets up an induced current in the loop of wire. This demonstration led to the development of the modern electrical generator.

**342. How does the electric generator work?** First we may define *the electric generator as a machine which is designed to convert mechanical energy into electrical energy.* The mechanical energy may come from an engine, from water power, or from wind power. If one were to try shoving a magnet up and down into a coil of insulated wire, he would find it an awkward way to produce electricity. Faraday, however, showed that an electric current can be produced in such a manner.

It is more convenient to mount a loop of wire on an axis, and rotate it between the poles of a horseshoe-shaped magnet. [See Fig. 16–4.] The lines of force are assumed to extend across between the poles of the magnet. As the loop is rotated between the poles, each wire in it cuts across the lines of force twice during each complete rotation, and an induced current of electricity is set up in the loop.

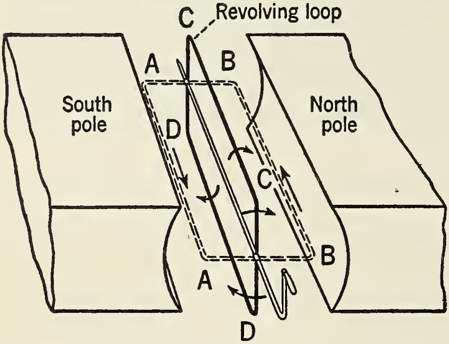



FIG. 16–4. A single loop of wire cuts lines of force as it is rotated between the poles of a magnet. A current flows through the loop in one direction during one half-revolution. It then flows in the opposite direction during the next half-revolution.

**343. What are the parts of a generator?** There are three important parts to a generator.

*a*) *The field magnet.* If there are to be lines of force to be cut by the conductors, there must be a magnet of some kind to produce such a field. A permanent magnet may be used, but in the commercial generator an electromagnet is used.

*b*) *The armature.* The rotating part is called the *armature.* It consists of many loops of insulated wire wound from

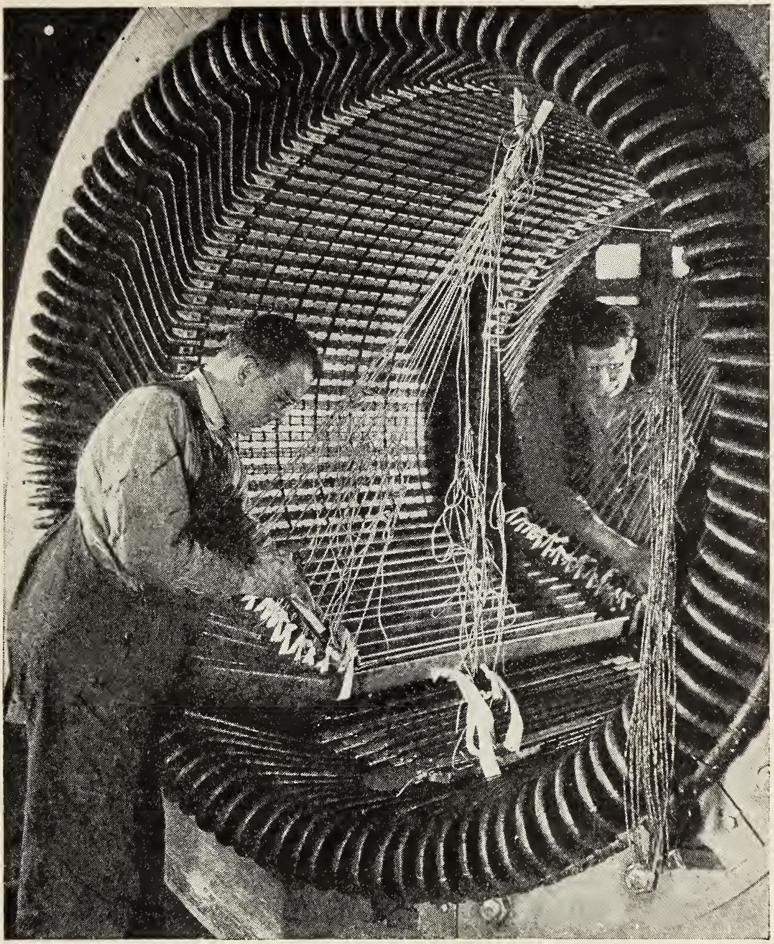


FIG. 16–5. These men are at work winding the armature of a large generator. The work is rather slow. (*Westinghouse Photo*)

end to end around an iron core. Each wire in each loop cuts the lines of force of the magnet twice during each revolution. [See Fig. 16–5.] Sometimes the field magnet rotates.

*c*) *The slip rings and brushes.* The brushes take the electric current from the slip rings, which take it from the armature. One end of the wire in each loop of the armature is

soldered to a brass ring which turns on the same axis as the armature itself. The other end of the wire in each loop is fastened to a second brass ring, which also turns on the axis of the armature. Strips of metal or blocks of carbon, which are called brushes, rest upon the slip rings as they rotate, and thus take up the current from them. From the brushes, the current is led by wires to the place where it is to be used. [See Fig. 16–6.]

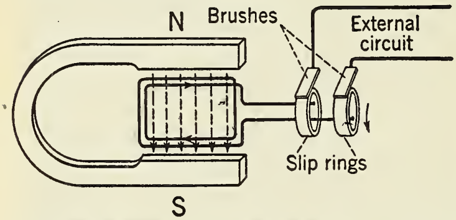



FIG. 16–6. The slip rings are connected with opposite ends of the armature coils. Brushes which rest upon the slip rings take the current from them to lead it into the external circuit.

**344. The commercial generator.** In the commercial generator, the field magnet is made exceedingly strong. The voltage which the generator builds up depends upon the number of lines of force that are cut per second. If the field is made strong, there will be many lines of force to be cut. If the armature has many loops of many wires each, there will be more wires to cut lines of force. The wires are wound on an iron core, because the iron affords a better path for the lines of force. Miles of wire are used in constructing the armatures of some generators. It is possible, too, to increase the number of lines of force cut per second by increasing the rate at which the armature is made to rotate.

**345. What is meant by alternating current?** When one wire of the armature moves upward past the north-seeking pole of the field magnet, it cuts lines of force in one direction. As it moves downward past the south-seeking pole, it cuts lines of force in the opposite direction. For that reason, one half the time the current in the coil of the armature is flowing in one direction, and the other half of the time it is flowing in the opposite direction. That gives what is called an *alternating current,* abbreviated A. C.

According to common practice, an alternating-current generator makes 120 alternations per second. That means that for 1/120th of a second the current flows in one direction through the filament of your lamp bulb, for example, and during the next 1/120th of a second it flows in exactly the opposite direction.

**346. What is meant by direct current?** For some purposes it is necessary to have a *direct current,* D. C., which always flows in one direction. It may be called a continuous current. It is possible to add to a generator a device called a *commutator,* which changes the alternating current that is produced in the armature into a direct current as it leaves the armature. Such a generator is called a *dynamo.* Voltaic cells and storage cells also produce direct current. [See Fig. 16–7.]

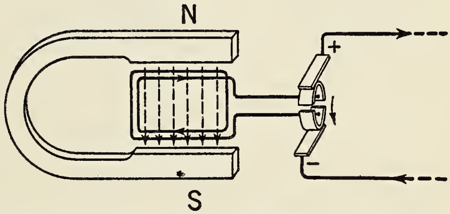



FIG. 16–7. The commutator changes the alternating current from the armature into direct current in the external circuit.

**347. For what purposes can direct current be used?** It is possible to use direct current for lighting, for heating, and for doing any kind of chemical work, such as plating, electrotyping, or charging storage batteries. It is also particularly useful for the making of an electromagnet, since direct current does not reverse the polarity.

It is not possible to vary the voltage of a direct current easily without the use of resistance, which of course means introducing friction. That means much loss of energy in the form of heat energy.

**348. For what purposes is alternating current used?** For the work of heating or lighting, alternating current is widely used. If alternating current is used to produce a magnet, it

is not usually satisfactory, because the poles must reverse at each alternation of the current. It can be used in the magnets of electric motors, however.

Alternating current cannot be used for any kind of chemical work, such as plating, extracting metals from their ores, electrotyping, or charging storage batteries. The alternating current from the house circuit is changed into direct current by a device called a *rectifier* to make it suitable for use in operating a radio set.

Alternating current has one decided advantage over direct current. By the use of a device called a *transformer,* it is possible to vary the voltage of an alternating current in any way that one desires. [See Fig. 16–8.] The voltage may be

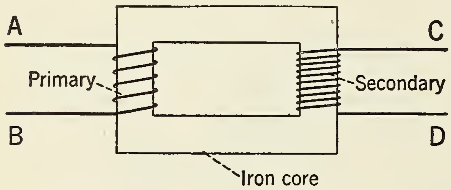



Fig. 16–8. The transformer may raise or lower voltage with little loss of energy.

stepped-up to 100,000 volts, or even more, to make it possible to transmit electric power economically for hundreds of miles. [See Fig. 16–9.] Then, with a loss of only 2 or 3 per cent, it may be stepped-down to 120 volts, a pressure which it is safe to use in our homes. A small transformer may also be used to reduce the 120-volt current of your lighting

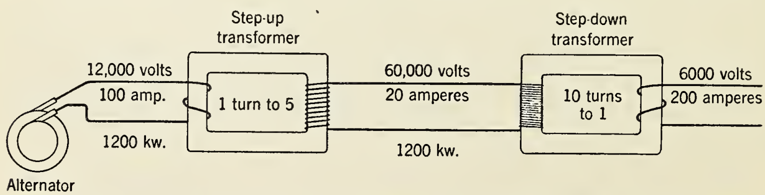



Fig. 16–9. Transformers are used to vary the voltage in the transmission of electrical power.

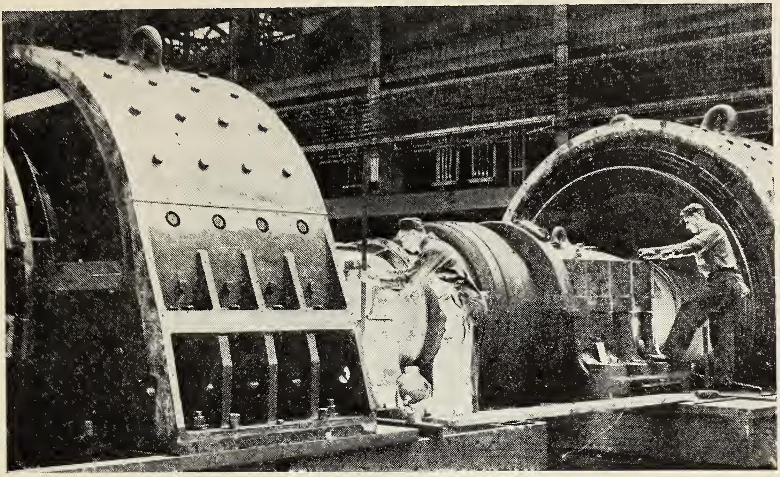


FIG. 16–10. These twin 5000-horsepower motors are used for operating the rolls in a steel mill for rolling hot iron at the Carnegie Steel Plant in Illinois. (*Westinghouse Photo*)

circuit to from 6 to 14 volts for ringing bells, operating Christmas-tree lights or toy electric trains.

**349. What is the purpose of an electric motor?** We have learned that the electric generator is a device used to transform mechanical energy into electrical energy. Can the process be reversed? It can, for *the electric motor is a device which is used to transform electrical energy into mechanical energy.* If one were to introduce a direct current into the armature of a direct-current dynamo, it would run backward as a motor. [See Fig. 16–10.]

**350. What are the parts of an electric motor?** There are many types of electric motors. The motor which operates on direct current has parts that are just like the parts of a dynamo. They are listed below.

*a*) *The field magnet.* A horseshoe-shaped electromagnet is used as the field magnet of the motor. The armature rotates between the poles of such a magnet. The field is magnetized by the direct current which is used to run the motor.

*b*) *The armature.* The motor armature, too, consists of a large number of loops of wire wound upon an iron core. The armature is mounted on a shaft, or axis, which is supported at each end by means of bearings.

*c*) *A current reverser is made up of a commutator and brushes.* By the use of the brushes, the direct current from some source used to drive the motor is led into the armature, and it is changed by the current reverser so that it will be alternating current in the armature.

*351. **What makes a motor rotate?** In a simple electric motor, we have two magnets. One is stationary, and the other one is free to rotate between the poles of the stationary magnet. In the stationary magnet the poles do not change. In the rotating magnet of the armature, the poles change twice during each rotation. That is, the north-seeking pole becomes a south-seeking pole after a half-rotation, and a north-seeking pole in the next. [See Fig. 16–11.]

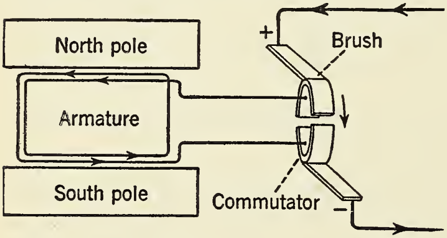



Fig. 16–11. The field magnet causes the armature to rotate by alternate attraction and repulsion.

Suppose we have the armature in the position shown in Figure 16–12. The south-seeking pole of the field magnet is

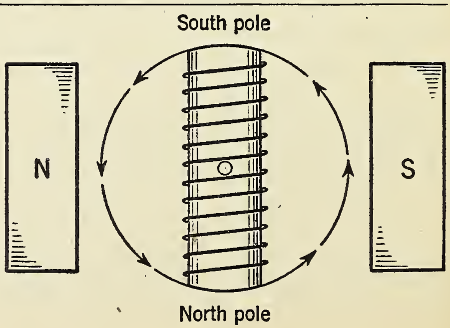



Fig. 16–12. The south pole of the armature is repelled by the south pole of the field magnet, and attracted by the north pole. What is true of the opposite pole of the armature?

repelling the south-seeking pole of the armature, and the north-seeking pole of the field magnet is attracting it. At the same time, the south-seeking pole of the field magnet is attracting the north-seeking pole of the armature, and the north-seeking pole is repelling it. All of the four forces of attraction and repulsion tend to turn the armature in the direction shown by the arrows of the dotted circle.

Why does the armature not stop when it has made a quarter-rotation and its south-seeking pole is near the north-seeking pole of the field, and its north-seeking pole is adjacent to the south-seeking pole of the field? It would stop, except for two things.

*a*) The commutator reverses the direction of the current flowing through the armature at that particular time, and that reverses the poles. [See Fig. 16–13.] Then the mutual attraction and repulsion continue to drive the armature on in the same direction.

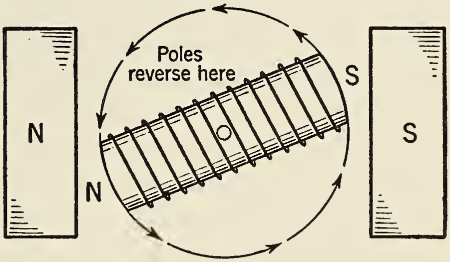



FIG. 16–13. The armature would stop between the poles of the field magnet unless the current reversed direction.

*b*) The *inertia* of the moving armature carries it on for a short distance while the poles are changing. Inertia is that property of matter that tends to keep an object in motion if it is in motion, and to keep it at rest when it is at rest.

A wheel for a belt may be fastened to the shaft on which the armature rotates. A belt from such a pulley wheel may be used to drive any kind of machinery. Sometimes the machine to be operated is attached directly to the shaft of the armature by means of gear wheels, or a direct drive connection.

**352. For what purposes are electric motors used?** The uses of electric motors are so many and so varied that one is not far wrong if he comes to the conclusion that the electric motor can do anything. A partial list is given here.

The electric motor is used to operate the compressor for making ice in our refrigerator. It may be used to drive a sewing machine to save the labor of operating the treadle. It can be used to turn the emery wheel or the grindstone for sharpening tools. It runs the washing machine to cleanse our clothes, and the vacuum cleaner which removes the dust and dirt from our rugs and carpets. The motor may be used to operate an electric shaver, hair drier, an electric fan, a clothes wringer, a food grinder, or an electric clock. The electric motor may be used, too, to whip the cream or to mix batter for the cake.

In the basement, the electric motor operates your oil burner, or it may open and close the drafts of the furnace, if you burn coal. In the use of the automobile, the electric motor drives the mechanical hand which cranks your engine. A small electric fan is used to circulate heated air through the interior of an automobile and to help defrost the windshield.

Powerful electric motors drive electric trains and street cars; they are used, too, for driving light delivery trucks, and for operating submarines when they are beneath the surface of the water. The cable used to lift elevators is wound on a large drum turned by an electric motor. Upon the farm, the electric motor may be used for such chores as splitting wood and milking the cows.

**353. What kinds of motors are in use?** Some types of motors, marked D. C. motors, will operate only on direct current. Other motors operate on alternating current only. They are known as A. C. motors. There is another type of motor that will operate almost equally well on either direct current or alternating current. It is called a *universal motor.* Many of the small motors used around the household are universal motors. It is a good plan, however, in buying

a motor-driven device, to inquire whether it can be used on either alternating- or direct-current circuits. In most homes, alternating current is used.

**354. Are motors expensive to operate?** Electric motors are rated either in horsepower or in kilowatts. They may vary in size from a tiny, sixteenth-horsepower motor to huge motors that furnish many horsepower. The electric motor in your refrigerator is probably a sixth or an eighth of a horsepower. Such motors use from 90 to 125 watts. That means that your refrigerator uses one kilowatt-hour of electrical energy in from 8 to 12 hours of continuous operation.

Motors are more economical to run than are heating appliances. For example, it usually costs two or three times as much to operate an electric flatiron, a coffee percolator, or a bread toaster for one hour as it does to run a vacuum cleaner for the same length of time. It costs five or six times as much to operate the various heating appliances just mentioned as it does to run an electric refrigerator. Of course your refrigerator motor usually runs more hours per day. In most localities, with an average price for electrical energy, it costs less than a cent an hour to operate an electric fan of ten inches in diameter.

## *Questions*

1. Why is the work of Faraday considered so very important?
2. What are some of the things that can be done with direct current that cannot be done with alternating current?
3. What do you understand by the term *alternating current?*
4. If the current used for an incandescent lamp is alternating, why doesn't the light flicker?
5. Make a list of four electrical units. For what man was each one named?
6. In what way does a direct-current electric motor differ from a dynamo?

7. What are the parts of a dynamo? What is the purpose of each part?

8. A coffee percolator operating on a 120-volt circuit uses 6 amperes of current. At what rate in watts does it use current? If electricity costs 8¢ per kilowatt-hour, what will be the cost of operating the percolator one hour each day for a month of 30 days?

9. Suppose your refrigerator has a motor that uses 100 watts. If the motor runs one-third of the time, what will it cost at 8 cents per kilowatt-hour to run the refrigerator for one month of 30 days?

# *We Are Traveling Farther and Faster*

THE earliest settlements in the United States were made along the Atlantic coast. There were no roads, and methods of transportation were very poor indeed. Those fearless individuals who ventured westward were forced to travel slowly, and they were likely to encounter hostile Indians. The trails followed the banks of the streams and rivers. Canoes and boats were used to transport the meager belongings of the early explorers. Later some of the trails were widened enough to permit ox carts to push through toward the interior where new settlements were being founded. Those were the days so clearly pictured in *The Prairie* and *The Pioneer,* novels by James Fenimore Cooper.

In the early part of the nineteenth century, steamboats began to ply up and down the rivers. Only a few years later some railroads were being built. If you read an account of the Lewis and Clark expedition in Jefferson's administration, you get a good idea of the vastness of the Northwest and the

difficulties encountered when the time came for colonization. The trek of the forty-niners across the plains and deserts furnished another picture. Not until the Union Pacific Railroad was opened did the development of the western part of the United States begin.

What is the modern picture? There are good roads in every state in the Union. In 1941, about 30,000,000 automobiles and motor trucks moved over our streets and highways, carrying passengers and freight. Fine new steam-, electric-, and Diesel-powered engines are used to drive streamlined trains, trucks, and buses from one part of the country to another. Hundreds of airports and landing fields make possible safe and rapid transportation between all the important cities in the United States by luxurious airliners.

## *Think about these!*

1. What keeps a huge ocean liner afloat?
2. When did the steam train come into common use? The automobile? The airplane?
3. How are explosions used in transportation?

## *Words for this chapter*

**Displacement.** The weight of water displaced by a ship or vessel in floating.

**Flotation.** Pertaining to floating objects.

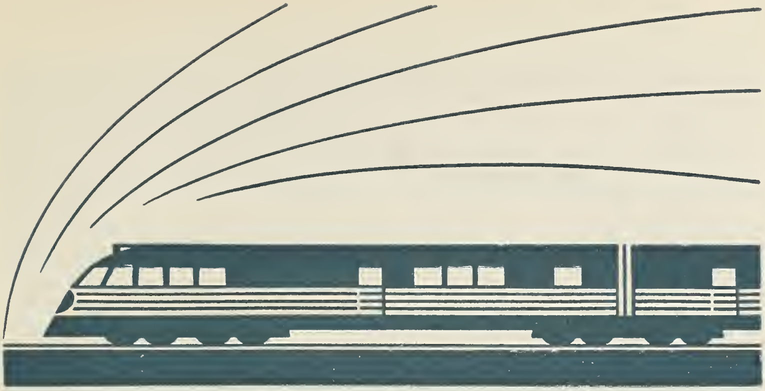
**Turbine.** A type of engine in which movable blades are driven by air, vapor, or water.

**Rotor** (rō′tẽr). The rotating part of a turbine or generator.

**Stator** (stā′tẽr). The stationary part of a turbine or generator.

**Carburetor.** A device which is used to mix air and vapor to form an explosive mixture.

**Cam.** A device used to change rotary motion into to-and-fro motion.



CHAPTER 17 —— UNIT 8

# How Has Man Improved Transportation by Land, Water, and Air?

**355. Our ancestors walked.** Many of the members of the present generation never walk if they can ride. Since an organ that is not used tends to waste away and disappear, it has been jokingly remarked that future generations will be born without legs. There is no question whether the cave men found their legs useful; they did not have our modern methods of transportation.

As man progressed, he tamed various beasts of burden, including camels, elephants, oxen, horses, and mules for use in carrying his goods from place to place. [See Fig. 17–1.] Such animals were even trained to carry man himself as he wandered in search of better hunting grounds or better pasture lands. In colonial days, fifty miles was a day's journey.

Centuries ago man learned to hollow out logs to float himself and his goods from one place to another. The American

FIG. 17–1. In Bombay, India, oxcarts are in use. One finds oxen, too, in Nova Scotia. Are such methods of travel ever used in the United States? (*Philip D. Gendreau*)

Indians were expert in building and paddling canoes. Boats that were larger were rowed by bands of oarsmen. Then men learned how to fasten sails to masts and yardarms and use the wind to drive their vessels hither and thither. One must admire the courage of Columbus, starting out on unknown seas in sailing vessels whose *displacement* was only from 60 to 120 tons. It took his vessels ten weeks to cross the Atlantic Ocean.

**356. What makes an object float?** If you shove your fist down into the water, your fist will crowd to one side, or *displace,* a certain amount of water. The amount of water it will displace is exactly equal to its volume, because *two things cannot occupy the same space at the same time.* But the water that is displaced pushes upward on your fist, producing *buoyancy.* How much is that upward push?

Archimedes, a Greek philosopher and mathematician, lived in the third century before the birth of Christ. Archimedes gave us the answer to the problem concerning the buoyancy

of liquids while he was attempting to find out whether a crown which had been made for Hiero, the tyrant of Syracuse, was made of pure gold. While at his bath, he noticed that his own body was buoyed up by the water and that it seemed to lose nearly all its weight. If you lie down in a bath tub nearly full of water, you will find that you can support yourself by placing two fingers of one hand upon the bottom of the tub.

This observation of Archimedes enabled him to solve his problem, and he is said to have been so much elated that he rushed through the streets shouting "Eureka! Eureka!" which means "I have found it."

But of greater importance than the problem of the crown was the principle that he discovered in solving the problem. We may state that principle as follows: *Any body immersed in a fluid* (either a liquid or a gas) *loses as much weight as the weight of the fluid it displaces.* Your fist is given an upward push equal to the weight of the water it displaces.

We push a wooden block down under water. When we release the block, we find that the water pushes upward on the block hard enough to make it float. If we push a block of iron down under the surface of the water, the water will push upward on the iron block, too. But the upward push in this case is not so great as the downward pull of gravity, and the block sinks. One cubic foot of fresh water weighs 62.4 pounds. Then every cubic foot of water that an object displaces will give that object an upward push of 62.4 pounds. If it weighs less than that amount, it will *float.* If it weighs more than that amount, it will *sink.*

**357. Will you sink or float in water?** Suppose that the volume of your body is exactly two cubic feet. Then when you are submerged, you will displace 124.8 pounds of water, which will give your body an upward push of 124.8 pounds. If you weigh only 120 pounds, you will float, and an additional push of 4.8 pounds would be required to push your body under water. [See Fig. 17–2.]

If, however, you weigh 128 pounds, then it will take an additional upward push or pull of 3.2 pounds to keep your body from sinking. If you can increase the volume of your body to 2.1 cubic feet by filling your lungs with air, you will then displace a little more than 131 pounds ($2.1 \times 62.4$ pounds). Then you can float without any trouble.

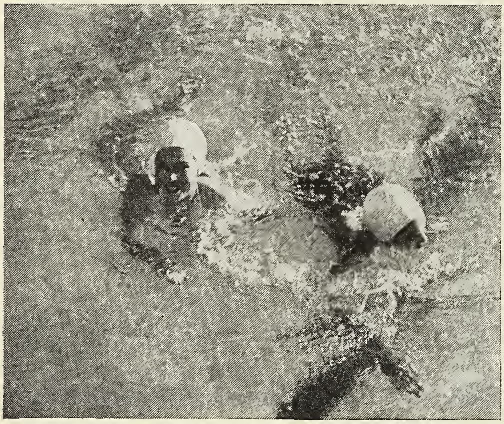


FIG. 17–2. The human body is usually slightly denser than water and it will not float easily when it is absolutely at rest. We may decrease the density of the body by filling the lungs with air. Then it is possible to float easily. (*Meisel from Monkmeyer*)

Life preservers are made of cork. If you fasten one cubic foot of cork around your chest, your volume will be 3 cubic feet, and you will then displace 187.2 pounds of water ($3 \times 62.4$ pounds $=$ 187.2 pounds). The cork has added to your weight about 15 pounds. Hence you have increased the buoyancy upon your body by a trifle more than 47 pounds, by the use of a life preserver containing one cubic foot of cork.

What would happen if you were to tie one cubic foot of lead to your chest? It would add to your volume just as much as one cubic foot of cork would do, but it would at the same time increase your weight by more than 705 pounds. Your direction would be that of "Davy Jones' locker."

**358. How is Archimedes' principle useful?** If one is planning to build a canoe, he must make it long enough, broad enough, and deep enough so that it will displace a sufficient

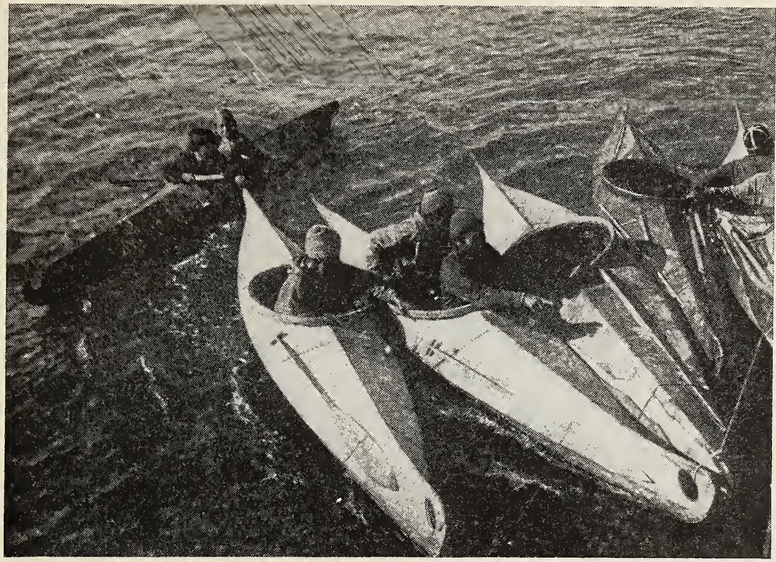


FIG. 17–3. Such kayaks are used in the waters of Alaska. Each one must displace enough water to carry the kayak and its load. (*Courtesy Office of Indian Affairs*)

amount of water to equal in weight the combined weight of the canoe itself and the load it must carry. Suppose, for example, that the canoe will weigh 80 pounds, and that it is designed to carry three persons who weigh 140 pounds each. *The canoe must displace 500 pounds of water if it is to float* ($500 \div 62.4 = 8+$). Hence the canoe must displace more than eight cubic feet of water. In actual practice, it must be made considerably larger in order to have a margin of safety. Then it will not sink so low in the water that the waves will break over it. [See Fig. 17–3.]

Some battleships weigh as much as 45,000 tons. In order to float, they must displace more than 90,000,000 pounds of water. Since sea water weighs 64 pounds per cubic foot, such a battleship must have enough of its volume beneath the surface to displace more than 1,400,000 cubic feet of water if it is to float. [See Fig. 17–4.]

In the making of life preservers, floating buoys, boats of

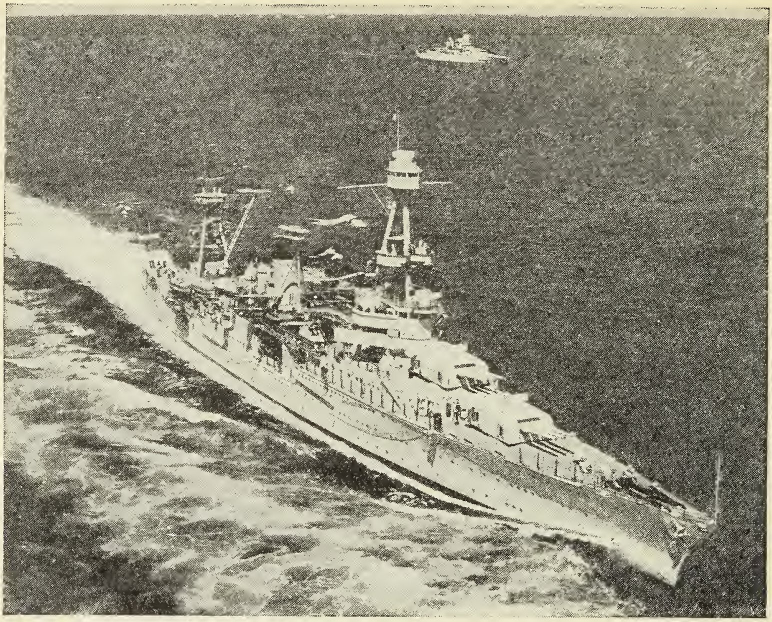


FIG. 17–4. This trim cruiser is the *U. S. S. Chicago.* It is strong enough to fight and fast enough to overtake an enemy. (*Philip D. Gendreau*)

all kinds, and even objects that float in the air, use is made of Archimedes' principle and the laws of *flotation.*

**359. The wheel is a marvelous invention.** Did you ever ask yourself how civilized man would get along without wheels? No one seems to know when or by whom the wheel was invented. Of course sleds can be used, but their sliding friction is enormous except when the ground is covered by snow and ice. In the Arctic regions the traveler still uses sleds pulled by large, strong dogs.

After the wheel came the two-wheeled cart and the four-wheeled carriage. This is probably the first practical use that was made of rolling friction, but the success of wheels is still described in the words of the song, "Wagon wheels! Wagon wheels! They just keep rollin' along." The old Romans had their two-wheeled chariots and their chariot

races. The colonists in America had their wagons and their carriages. The covered wagon was used by the forty-niners as they crossed the Great Plains and the deserts in their mad rush to the gold fields of California.

Over poor roads, with the wheels dropping into holes and ruts, a carriage ride was none too comfortable. To make the ride more comfortable, either the seats or the entire frame of the carriage was mounted on flexible steel springs. Then the wheels were rimmed with solid rubber. The pneumatic tires came later, and now we do not feel comfortable riding over even improved roads unless we ride on air-cushioned tires, and have shock absorbers and deep-cushioned seats, too.

**360. The coming of the iron horse.** Old Dobbin was dependable, but he was not very fast. Oxen traveled fast enough to pull a farm wagon or a plow. But a week was too long a time to take to travel from New York to Washington, or to carry the mail from one city to the other. Man began to use his inventive genius to find some way to travel more rapidly, and the "horse and buggy" days began to disappear.

Newcomen is said to have given us the first steam engine, but nothing much came from his early attempts to use steam as a source of power. In England, we find James Watt, who watched the lid bobbing up and down on the teakettle. He wanted to know how to harness the power of steam and use it to do work; and he found out. Are we not correct in thinking that as a result of a boy's curiosity the practical steam engine was born?

It was George Stephenson, the "founder of railways," who first made travel by rail a success. His locomotive, called the *Rocket,* won in a competitive trial for locomotives in 1829, and in the year 1830 the Liverpool and Manchester Railroad was formally opened.

**361. What is the principle of steam power?** If the pressure does not change, one quart of water will take up about

1700 quarts of space or room when it changes into steam. That is what happens in a steam boiler, when the pressure of the air upon the surface of the water is 14.7 pounds per square inch of surface. But what will happen if the steam is led from the boiler into a closed space where the steam cannot expand? Of course its pressure will build up and increase tremendously. It soon rises to 60 pounds per square inch, then to 80 pounds per square inch, and finally to several hundred pounds for every square inch of the container. It may even burst the walls of the steam chest, or the container in which it is being confined. Such steam pressure may be put to work pushing to and fro a piston in the cylinder of a steam engine.

**362. What are the essential parts of a steam engine?** First of all, it is necessary to have a steam boiler to supply steam in an efficient manner and in large quantity. It may be built into the same unit as the engine itself, or it may be entirely separate, even in a different room. In such a case, the compressed steam is piped from the boiler to the steam engine.

*a) The steam chest.* From the boiler, steam enters the steam chest, which is merely a thick-walled compartment containing an opening for the entrance of the live steam, an exit pipe for the "spent" steam, and two openings into the cylinder of the engine. A valve inside the steam chest slides to and fro, alternately opening and closing the two openings into the cylinder of the engine.

*b) The cylinder.* The engine cylinder is made by boring a hole in a block of steel. Such a hole is several inches in diameter, and possibly two feet or more in length. The cylinder is closed at the ends by cylinder heads which are bolted firmly to the steel block of which the cylinder was made. [See Fig. 17–5.]

*c) The piston.* Inside the cylinder there is a piston which may be slid to and fro in the cylinder. It must fit the cylinder so perfectly that steam cannot get past it. A strong

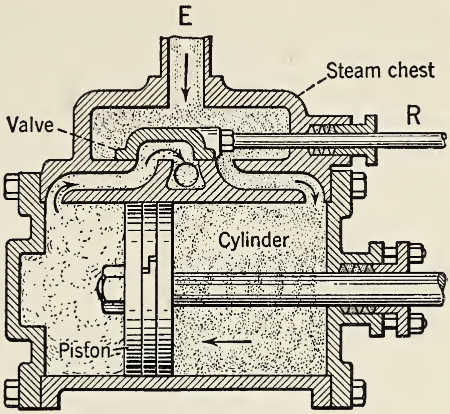



FIG. 17–5. The steam enters the steam chest and flows into the cylinder where it pushes the piston backward and forward, to and fro, or, in some cases, up and down. The force comes from the expansion of the steam.

steel shaft, attached to one side of the piston, leads out through an opening in one of the cylinder heads.

**363. How does the steam engine work?** Suppose we refer again to Figure 17–5. The steam from the boiler enters the steam chest through the entrance pipe at E. It moves past the rod R and enters the *right-hand end* of the cylinder. Its expansive force pushes the piston toward the left. You can imagine that it is pushed forcibly, because there may be 100 square inches of surface on the side of that piston, and the steam pressure may be 100 pounds or more on each square inch. As the piston is being pushed over toward the left end of the cylinder, the valve in the steam chest moves over to the right. That permits steam to enter the *left end* of the cylinder. This live steam pushes the piston forcibly to the right. In the meantime, the steam that was used to push the piston toward the left is now "spent," and it passes out of the cylinder through the same pipe by which it had entered. It is forced, however, by the shape of the valve to go out into the air through the exit pipe, the end of which is shown just beneath the valve.

Then the whole process is repeated again and again. As the valve slides from left to right and vice versa, it permits steam to enter first one end of the cylinder and then the

other end. The steam in the cylinder drives the piston, forward and backward, many times per minute.

364. **How have the railroads grown?** The *Rocket,* which was built by Stephenson, is a pygmy compared to some of the giant locomotives of modern times. Possibly you were fortunate enough to visit the World's Fair in New York City and see the pageant called *Railroads on Parade.*

Stephenson's *Rocket,* which may be considered the father of them all, could haul a load at the then almost unheard-of speed of twenty miles per hour. After 1830, railroad building began to spread in England. The first line built in the United States was not a very long one, extending from Baltimore to Washington. That was the small beginning. Now there is a vast network of railroads in the United States with a total mileage of about 240,000. If you count the switches and the double and quadruple tracks, the number of miles of tracks reaches a figure that is well above 400,000 miles. Trains thunder over such tracks at speeds of from 50 to 90 miles per hour, with some streamlined trains doing well over 100 miles per hour. [See Fig. 17–6.]

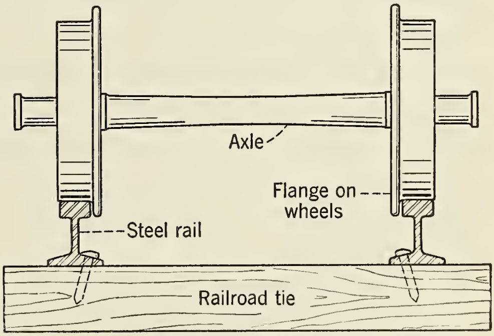
FIG. 17–6. The streamlined train known as the *Rocket.* (*Courtesy Chicago, Rock Island, and Pacific R. R.*)

365. What things have made fast railroading possible? Possibly you have stood beside a railroad track when a huge locomotive whizzed past you, hauling a load of several hundred tons. Did you ever stop to wonder how it is possible for trains to travel as fast as they do, with comparative safety? Several factors have contributed toward making such fast travel possible.

*a*) *The roadbed.* Some of the early trains ran on tracks made of wooden planks. Cheap methods of making steel came when railroad business was expanding. The steel rails now in use are so heavy that they are not likely to bend or break. The steel is of such good quality that the rails do not usually split at the ends.

The ties are laid, and rock or crushed stone is tamped in around the ties to make a solid roadbed. The rails are so firmly fastened that they do not spread easily; the foundation is better drained, and washouts are not likely to occur.

Fig. 17–7. The flanged wheel keeps the train from running off the track.




*b*) *The flanged wheel.* If you look at Figure 17–7, you can see the nature of the *flanged* wheel, which was invented by Edwin Stevens, of Hoboken, New Jersey. He is also the founder of Stevens Institute. The flange on the inside of each wheel prevents the wheels from slipping off the rails, even when rounding a curve at high speed.

*c*) *Increased horsepower.* Locomotives have grown up since the days of the *Rocket.* They have grown in length,

too, and in weight. Some of the largest steam locomotives weigh over 500 tons, and they develop several thousand horsepower. Electric locomotives are even more powerful. The *Yellowstone* locomotive is 125 feet long and weighs 1,125,000 pounds. It can pull a load of 4000 tons up a 1 per cent grade. A mechanical stoker can deliver to the firebox 22½ tons of coal every hour.

*d) The Westinghouse airbrake.* If railroad men still had to depend upon the old hand brake, fast trains could not be run safely. It took too long to apply the brakes by hand to each of the cars in a long train. Now, by means of the Westinghouse airbrake, brakes can be applied to every car in the train at one time and the whole train can be stopped quickly. The brakes may be applied by the engineer, while sitting in the cab of his locomotive.

**366. The coming of the steamboat.** It costs little to operate a sailboat when the wind blows. When the sea is calm, progress falls to zero, and much time is lost. In his desire for speed, man conceived the idea of placing a steam engine in a boat and using steam power to drive the boat. Robert Fulton is generally considered the inventor of the first successful steamboat, which came into use early in the nineteenth century. Sometimes the steam engine was used instead of sails in calm weather, and sometimes it replaced sails altogether.

In the early steamboats, the steam engine turned a large shaft, to the ends of which large paddle wheels were attached. These paddle wheels were on either side of the vessel, or sometimes a paddle wheel was attached to the stern. The wheels drove the steamer forward through the water at a fairly high speed, compared to that of the older sailboats; but when the boat rolled, and first one paddle wheel and then the other was lifted above the surface of the water by the waves, progress was slow indeed. [See Fig. 17–8.]

For ocean travel, the screw propeller is attached to the stern of the vessel, well below the surface of the water. Just

Fig. 17–8. Such steamboats are used to tow log rafts on the Mississippi River. They are not handicapped so much as the sidewheelers. (*Ewing Galloway*)

as an electric fan pushes the air away from it as the blades rotate, so the blades of the screw propeller push the water from them as they turn rapidly. The resistance which the water offers reacts against the propeller to push the boat forward, just as it reacts against your hands and arms when you take strokes in swimming. Side-wheelers are still in use in the rather shallow waters of some rivers.

**367. The modern liner became a floating palace.** The *Queen Mary*, a Cunard-White Star liner, crossed the Atlantic Ocean from Cherbourg, France, to New York harbor in July, 1936, a distance of 3096 miles in 4 days, 9 hours, and 44 minutes. The average speed was nearly 34 miles per hour. Compare that time with the 70 days that Columbus and his sailors were tossed about on the stormy Atlantic. In normal times, liners were floating palaces with their spa-

cious dining rooms, their swimming pools, and their decks fitted for sports of many kinds. Torpedo-boats and destroyers plow through the water at speeds of 40 knots or more. The knot equals a speed of 6080 feet per hour, and a speed of 40 knots is equal to about 46 miles per hour. The high speed of ocean vessels is made possible as a result of the invention of the *steam turbine.*

**368. What is the steam turbine?** Just as the wind in blowing against the blades in the wheel of a windmill causes the wheel to turn rapidly, so steam directed against the many rows of blades fastened to a shaft can make the shaft spin rapidly. The blades and the shaft are known as the *rotor.* In Figure 17–9, we see the rotor of a steam turbine mounted on the base, which is called the *stator.* The upper part of the stator has been removed to show the rotor inside.

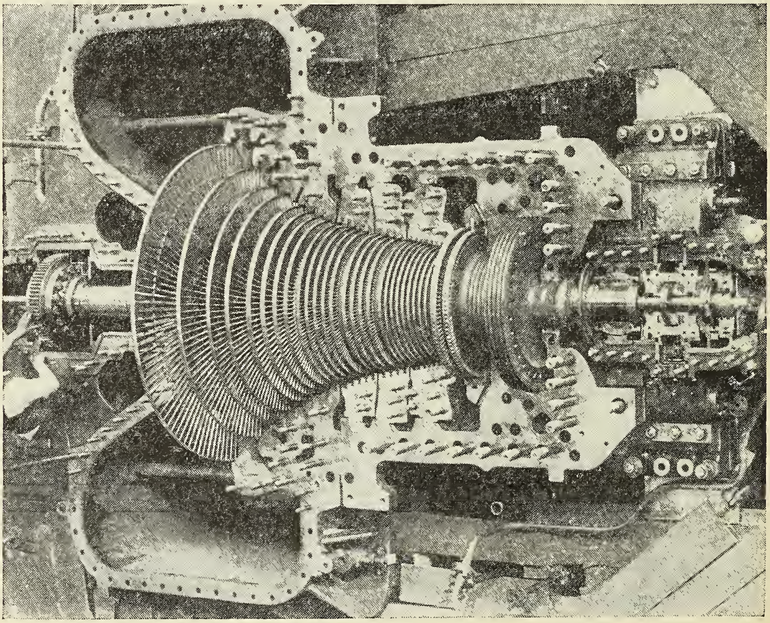


FIG. 17–9. At a speed of 3600 revolutions per minute this large rotor can develop 20,000 kilowatts or about 27,000 horsepower. (*Westinghouse Photo*)

The turbine engine is more efficient than the steam engine described in section 362, especially when driven at high speed. It takes up less floor space in proportion to the horsepower it develops, and it does not vibrate so much. Unfortunately, its direction cannot be reversed.

**369. Why does water have energy?** The heat from the sun causes water to evaporate. The winds carry the moisture inland, sometimes to high elevations. *Thus work is being done in lifting the water above sea level.* The water at the higher elevation has what is called *potential energy.* That is energy due to its position. It is potential energy because it is capable of doing work.

In order to do work, the water must flow downhill. If it flows down a gradual slope, one cannot use it to develop much power. If it flows down a steep slope, or plunges over a precipice as it does at Niagara Falls, then it can develop a great deal of energy. The amount of water power that a stream can produce depends upon the volume of water in the stream, the vertical distance it falls, and the time it takes to fall.

**370. How can the potential energy of water be changed into power?** Everyone knows Niagara Falls either from pictures or from a visit to that marvelous cataract. If you were to carry one cubic foot of water (62.4 pounds) from the base of the Falls up to the top (about 160 feet), you would be doing 9,984 foot-pounds of work ($160 \times 62.4$ pounds $=$ 9,984 foot-pounds). It would probably take you about two and a half minutes to lift the water by the use of a rope and fixed pulley, if you worked at the rate of one-eighth of a horsepower. The average man power is about one-seventh of a horsepower.

But when the water plunges over the brink of the Falls, it takes just a little more than *three seconds* for it to fall the entire distance. In falling, that cubic foot of water that you lifted to the top of the Falls, develops almost *six horsepower.* Now if you think of the thousands of cubic feet of water that

FIG. 17–10. The Victoria Falls of the Zambesi River in Africa are higher than Niagara Falls. They have not been harnessed to produce power for man's use. (*Philip D. Gendreau*)

are plunging over Niagara Falls every second, you can understand why it is estimated that Niagara Falls could develop 7,000,000 horsepower if it were completely harnessed. The level of the water in Lake Erie does not vary a great deal, and the water from that great lake flows down the Niagara River, thus keeping the Falls supplied with water.

You doubtless know that millions of tons of coal are burned to supply power for stationary engines and for locomotives. The supply of coal in the United States is very great, but it is not inexhaustible. Therefore more and more attention is being given to the harnessing of our rivers and the developing of their water power. The supply of "white coal" is not likely to fail. [See Fig. 17–10.]

**371. How do men harness rivers?** We put a harness on a horse if we wish to have him do useful work. Then we can use his force to our advantage. In a similar manner, man has

learned how to harness the water in a river in order to use its great store of energy to advantage. There are several ways in which this is accomplished.

*a*) He may use the energy of a swiftly flowing stream that has a large volume of water. The *undershot water*

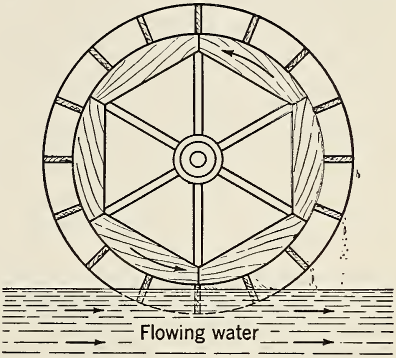



FIG. 17–11. The undershot water wheel makes use of the energy from flowing water. This is another example of putting water to work.

*wheel* of Figure 17–11 shows how this is accomplished. The swiftly flowing water directs its energy against the paddles to turn the wheel.

*b*) He may use a small volume of water to turn the *overshot water wheel* of Figure 17–12, if there is a fall of some

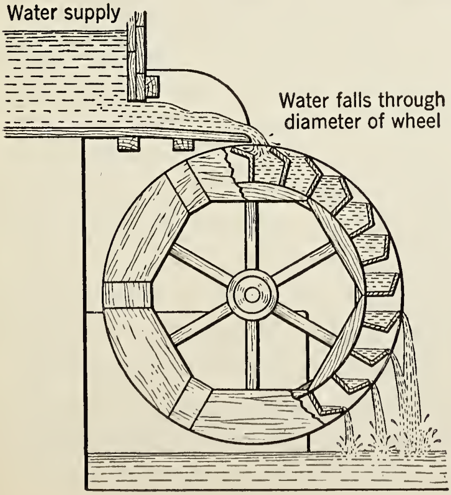



FIG. 17–12. Here man depends upon the energy from falling water to operate such a water wheel. The greater the height of the fall the more power one can obtain. Such a water wheel is fairly efficient.

15 feet or more. The water fills the bucket-like blades near the circumference of the wheel, which usually has a rather large diameter. This wheel is more efficient than the undershot water wheel.

*c*) He may also use a more efficient device known as the *Pelton wheel.* In the use of such a wheel, the water is led downward through a pipe and directed against the blades of the Pelton wheel. Little energy is lost, because the water is directed against the blades at such an angle that it is very effective. [See Fig. 17–13.]

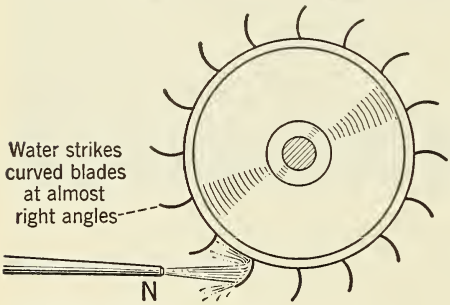



FIG. 17–13. In the Pelton wheel the water is directed against the blades at such an angle that little energy is wasted.

*d*) The *water turbine* is extensively used. The water from the brink of some falls flows down through a tube called a *penstock.* At the base of the falls it strikes against a set of curved blades mounted on a vertical shaft, just as steam impinges upon the blades of the rotor of a steam turbine. The upper end of this vertical shaft may have attached to it the armature of a huge electric generator. As the water turns the turbine rapidly on its shaft, its energy is transformed into electrical energy. Such an installation is called a *hydroelectric power development.*

Of course it is possible to use the steam turbine to develop electricity in a similar manner. The armature of the generator may be wound upon one end of the same shaft upon which the rotor is mounted. Steam energy is used to turn the rotor, which also turns the armature and generates electricity.

**372. How does man increase the amount of water power?** Man is not satisfied to use merely the water power that can be produced by natural falls. He must build dams to create new falls to develop more water power. For that reason, engineers have planned the construction of large dams to create artificial lakes which will supply enormous quantities of water power. There are 66 such dams in the United States that are more than 200 feet in height. One of the best known is Boulder Dam.

*a*) *Boulder Dam.* At the present time Boulder Dam is the highest dam in the world. It was completed March 1, 1936, almost five years after work on it was begun. It was built for several purposes: to control the flood waters of the Colorado River; to supply water for irrigation purposes; and to develop water power.

This dam rises 726 feet above bedrock. Eventually, it will raise the water of the Colorado River 582 feet above its former level. It will create an artificial lake 115 miles long and 40 miles wide. The first unit for developing power has been completed. It can supply 1,835,000 horsepower.

*b*) *Bonneville Dam.* This dam is built across the Columbia River at Bonneville, Oregon. It is designed to furnish power, and also to raise the level of the water above the dam to aid navigation. This project is interesting, too, because fish ladders have been built to permit the salmon entering the Columbia River to move up to their spawning grounds.

*c*) *Grand Coulee Dam.* This dam is the biggest thing ever built by man. It is 4300 feet long, about 4/5 of a mile. Its height is equal to that of the Washington Monument. At its base it is 500 feet thick, one and two-thirds times the length of a football field. There is enough concrete in the dam to make a pile twice as big as the Great Pyramid. When the Columbia River rises to the top of the dam, it will form a lake 150 miles in length. This dam will supply abundant power for the central Washington area and supply water to irrigate at least a million acres of land.

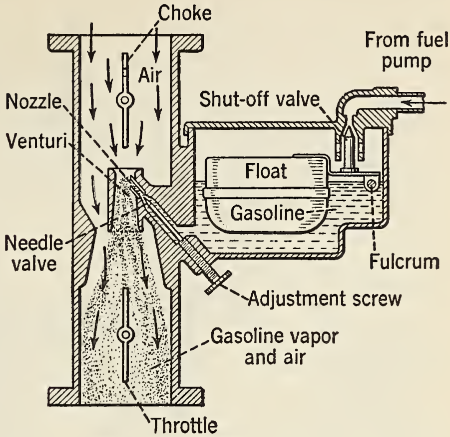
**373. Upon what principle does the gas engine work?** The invention of the gas engine marked another step in advance in the field of transportation. In the steam engine, heat energy produces steam, and the steam expands to produce mechanical energy. *The fuel is burned outside the engine itself.* In the operation of the gas engine, heat energy is also changed into mechanical energy. In this case, however, *gasoline vapor is burned explosively inside the cylinder of the gas engine itself.* Such an engine is called an *internal-combustion engine,* because the actual combustion occurs inside the cylinder walls.

One type of explosion is caused by *almost instantaneous oxidation of the burning fuel.* The heat causes the burning gases to expand tremendously, possibly to tens of thousands of times their original volume. Suppose the bed upon which you are sleeping should suddenly, in one-sixtieth of a second, expand to 10,000 times its size. Can you imagine that you and the walls of your bedroom might be pushed aside in an extremely rude manner?

Liquid gasoline burns, but it does not explode. Pure gasoline vapor burns, but it does not explode. If, however, you evaporate the gasoline and mix its vapor with the proper amount of air, then you have a mixture that is a much more powerful explosive than dynamite. There is more potential explosive energy in ten gallons of gasoline than there is in one ton of dynamite. By the use of a *carburetor* it is possible to form from gasoline and air an explosive mixture, explode it inside the cylinders of a gas engine, and use the explosive force to drive the piston in the cylinder of the engine.

**374. How does the carburetor work?** A fuel pump is used to pump gasoline from a tank at the rear of an automobile to the carburetor. [See Fig. 17–14.] It flows into a small compartment of the carburetor, where a float keeps the level of the gasoline liquid at a proper height. Then it flows through a small opening into the mixing chamber,

FIG. 17–14. Since liquid gasoline does not explode, a carburetor must be used to make it evaporate. Then its vapor is mixed with air before it enters the engine.




where it is mixed thoroughly with the air which is admitted just fast enough to form an explosive mixture with the gasoline vapor. When the throttle is opened, the explosive mixture is then pushed into the cylinders of the gas engine.

**375. Of what parts does the gas engine consist?** A gas engine may have a single cylinder, or it may have two, four, six, eight, or even more. Figure 17–15 shows a sectional view of a gas engine. Note how the parts are arranged.

*a*) *The cylinder.* A block of iron is so cast that its walls will be hollow to permit water to circulate through them. The cylinder is made by boring a hole about 3 inches in diameter in the cast iron block.

*b*) *The piston.* Inside the cylinder we have the piston. It is free to move up and down in the cylinder, but it fits the cylinder so tightly that the mixture of explosive gases cannot get past it. There is a rod which connects the piston with the crankshaft by means of which the car, for example, is driven.

*c*) *The cylinder head.* To help form an explosion chamber at the top of the cylinder, a metal cylinder head is firmly bolted to the cylinder block. It fits so tightly that gas cannot escape around the edges. It is also water-cooled. You will observe that there is a *spark plug*, which is screwed into the cylinder head.

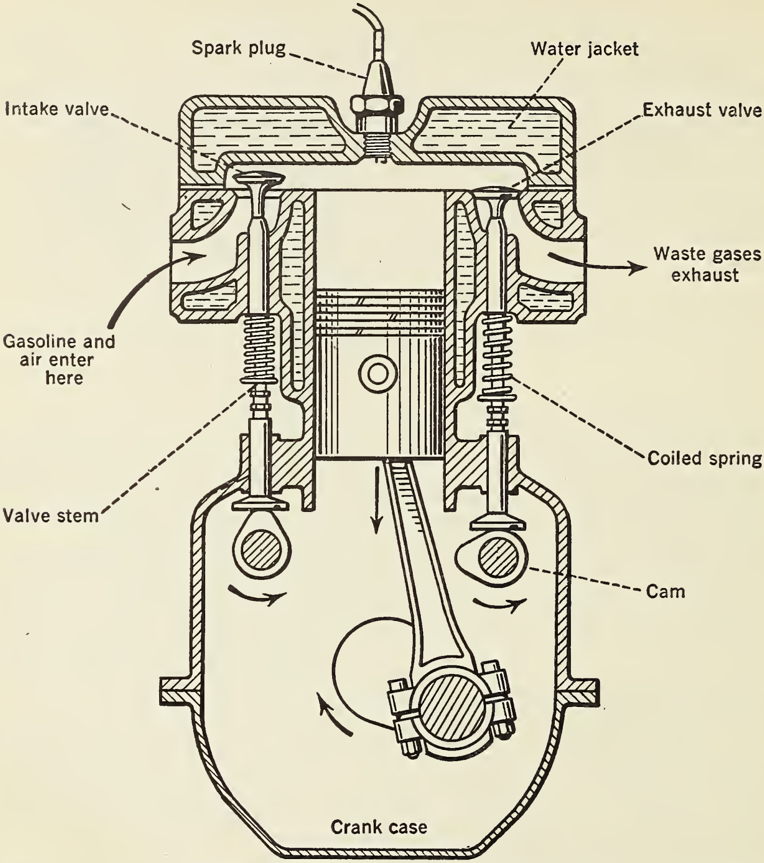



FIG. 17–15. A cross-sectional view of one piston and cylinder of a gas engine.

*d*) *The valves.* When we wish to control the flow of a liquid or a gas, we use a valve. There are two valves for each cylinder of a gasoline engine. The *intake* valve opens to permit the explosive mixture from the carburetor to enter. The *exhaust* valve opens to permit the waste gases to escape after the explosion. Both valves are controlled by *cams.* The valves in this L-head type of engine or motor are both placed on the same side of the engine in actual practice. For

the sake of simplicity, they are shown on opposite sides in the diagram. In some gas engines the valves are in the cylinder head.

**376. How does a gas engine work?** In Figure 17–16, we have shown four different views of a single-cylinder engine.

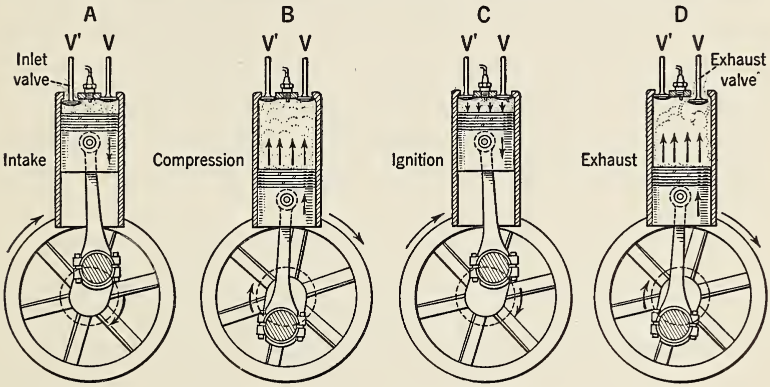



FIG. 17–16. The gas engine is a four-stroke engine. There is one power stroke for two complete revolutions of the crank shaft.

They represent the position of the piston and the valves in each of the *four strokes* of a gas engine.

*a*) *The intake stroke.* When one cranks a gas engine, either by hand or by the use of a self-starter, he pulls the piston downward the full length of the cylinder. That produces a partial vacuum in the explosion chamber above the piston. The inlet valve opens and the explosive mixture from the carburetor is pushed into the cylinder.

*b*) *The compression stroke.* As we continue to crank the car, the piston moves upward and compresses the explosive mixture. The cranking is hard now, because the volume of the gas must be reduced to about one-sixth its former volume. Of course both valves must be closed, because there could be no compression if either valve were open.

*c*) *The explosion stroke.* When the piston reaches the top of the cylinder, or nearly so, an electric spark is produced at the spark plug. The spark ignites the mixture, which ex-

plodes violently. The piston is the only thing that is movable. The expanding gas drives the piston downward with great force. This is the *working stroke of the engine.* Naturally, both valves must be closed.

*d*) *The exhaust stroke.* Before the cylinder can be refilled with more of the explosive mixture, the waste products from the explosion must be removed. As the piston moves upward, the *exhaust* valve opens to permit the escape of the waste gases. Then the whole operation begins again. For two complete turns of the crankshaft, we have one working stroke. What keeps the engine running between working strokes?

**377. Why is a flywheel used on an engine?** We have learned something about inertia. A body in motion tends to remain in motion. The flywheel, which is attached to the crankshaft of a gas engine, has a rather heavy rim. When we crank the car, we start the flywheel turning, too. That makes it harder to crank the car. But when the first working stroke occurs and the crankshaft starts to rotate at the speed of several hundred revolutions per minute, the inertia of the flywheel keeps it running smoothly between successive working strokes.

Some of the early automobile engines had only a *single* cylinder. The flywheel for such an engine weighed about 300 pounds. Later, two-cylinder engines began to be used. Then the number was increased to four, to six, and to eight. The explosions occur in succession in each cylinder. For that reason, an eight-cylinder engine gives a fairly steady flow of working strokes, or power strokes.

**378. The modern automobile.** Probably your father can remember when a horseless carriage was so uncommon that he and other members of his family went to the window to see one pass. At about the time that the First World War began, there were only about one and one quarter million cars registered in the entire United States. Now any one of seven states has that many or more, and the total number of

cars in the entire country is more than 30,000,000. In fact, there are more cars in the United States today than there are telephones, and more telephones than bathtubs.

Without the gas engine, the modern automobile would hardly be possible. It is true that both steam and electricity have been tried for the driving of cars, but nearly all cars are now operated by gas engines that deliver from 50 horsepower to more than 140.

To accommodate motor travel, super-highways have been built. From two lanes in width, highways have grown to four, six, or even eight lanes in width. The trip from New York to Washington that required a week in colonial days can now be made with reasonable safety in from 8 to 10 hours. An automobile can be driven across the continent from New York to San Francisco in about the same time that a horse and rider would need for a trip from New York to Washington, D. C.

In normal years, engineers bring out new models that ride more easily, that furnish greater economy, that provide greater safety, that are easier to handle, and that offer greater freedom from trouble of all kinds.

**379. What are the parts of an automobile?** A person needs a fairly good course in the science of physics to understand all the principles that are used in the modern automobile. It will be easier if we think of it as consisting of three main parts.

*a*) *The power plant.* The engine and the manner in which it produces power have already been discussed. It is mounted on blocks of rubber and firmly attached to the frame of the car. The engine drives three pumps; a fuel pump, an oil pump to keep oil circulating around the moving parts of the engine, and a water pump which keeps water circulating around the engine to keep it from becoming overheated. The engine also drives a fan to help in the cooling process, and a small generator which produces the electricity needed to charge the storage battery. The *carburetor*

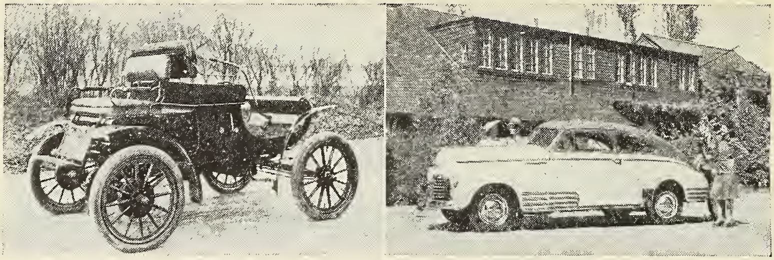


FIG. 17–17. Can you imagine the model that will make the modern car, on the right, look as outdated as the 1904 model, on the left? (*Courtesy General Motors Corp.*)

is attached to the engine, and so is the *distributor,* which supplies the electric spark to each cylinder at the right time.

*b*) *The body.* The car body has been much improved in recent years. It is stronger because it is rounded in shape and it is made entirely of steel. It is hung lower than formerly, and for that reason the car is not so likely to be overturned. [See Fig. 17–17.] It is suspended on long, flexible springs or on coiled springs, and shock absorbers are used, too, to make riders more comfortable. In many modern cars the body is insulated against both heat and sound. A heater inside the body keeps the car warm in winter and also helps to keep the windshield free from snow and ice.

The V-shaped windshield gives broader vision. The slanting rear window and the slanting windshield help to prevent glare from the headlights of other cars, or from light reflected from wet pavements. All the windows of the body are likely to be equipped with shatterproof safety glass.

There is an instrument panel that may furnish considerable information to the driver. The *gasoline gauge* shows the driver when the gasoline tank needs to be refilled. An *oil gauge* shows whether or not the oil pump is supplying the engine with oil. A *thermometer* shows the temperature of the water circulating around the engine. The *speedometer* shows the speed at which the car is moving. An *ammeter* shows when the battery is charging or discharging.

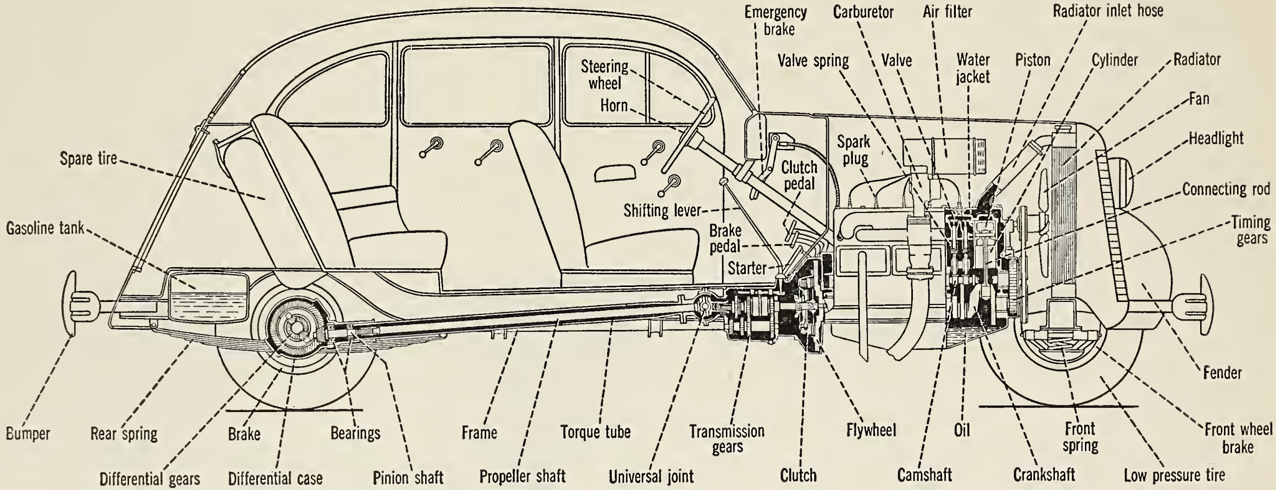



FIG. 17–18. This is the way your father's car might look if you took a long saw and cut the car entirely through from front end to rear end. Some important pieces through which you would cut include the bumper, radiator, fan, pistons, cylinders, flywheel, universal joints, propeller shaft (or drive shaft), differential, gasoline tank, and rear bumper. Of course you would cut through the body and seats, too.

*c*) *The chassis* (shăs′ĭ). With the frame of the car we shall include the wheels, or the running gear. The metal frame which supports both the engine and the body is attached to the front and rear axles. The frame is made of exceptionally strong steel, and it is strongly braced.

We can possibly get a better idea of how the engine drives the rear wheels of the car if we refer to Figure 17–18, which shows the parts of a car as they would appear if a car were sawed through from front to back.

The flywheel is attached to the rear end of the crankshaft. Around its outer circumference it has cogs to which the cogs, or teeth, of the self-starter can be engaged when the starter cranks the car. The *self-starter* consists of a small electric motor operated by electricity from the storage battery.

Back of the flywheel we have the *clutch*. [See Fig. 17–19.] The clutch is designed to bring together *gently* the revolving crankshaft of the engine and the stationary drive-shaft of the car when one is starting a car from rest. It is not an easy thing to do. We have started the engine, and possibly its crankshaft is revolving at a speed of 1200 revolutions per minute. The clutch must then bring the drive shaft up to the same speed without jerking. As we engage the clutch by raising our left foot from the clutch pedal, strong springs push together two plates, one of which is covered with friction material. The plates slip at first, then hold firmly, and turn together at the same speed. When we push the clutch pedal all the way down to the floor, we separate the plates and the engine is disconnected from the drive shaft and the

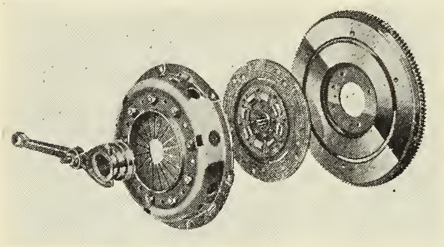


FIG. 17–19. The clutch is used when starting a car, when stopping, and when shifting gears. (*Courtesy Chevrolet Motors Sales Corp.*)

rear wheels. The clutch is used when starting a car, in shifting gears, and when stopping. In some fluid-drive cars the shifting of gears is automatic, and no clutch is necessary.

A short shaft connects the clutch with the *transmission gears.* These transmission gears are enclosed in a metal housing. They are almost directly beneath the floor boards in front of the forward seat. They consist of gear wheels which have different numbers of teeth. In our study of the bicycle, we learned that wheels having a different number of teeth can be used to vary the speed. By means of a gear-shift lever, it is possible to engage with one another those gear wheels which will give the speed that is desired. For example, in *low* speed the engine may be running fast and the crankshaft revolving rapidly, but the gears reduce the speed so that the rear wheels turn slowly. When the gears are set at *intermediate speed,* the engine may be running at the same speed as before, but the rear wheels will be turning more rapidly than they do when the gears are set at low speed. At *high* speed, the rear wheels turn still faster, even when the engine speed is unchanged. The speed of the engine is controlled by the accelerator lever which regulates the throttle.

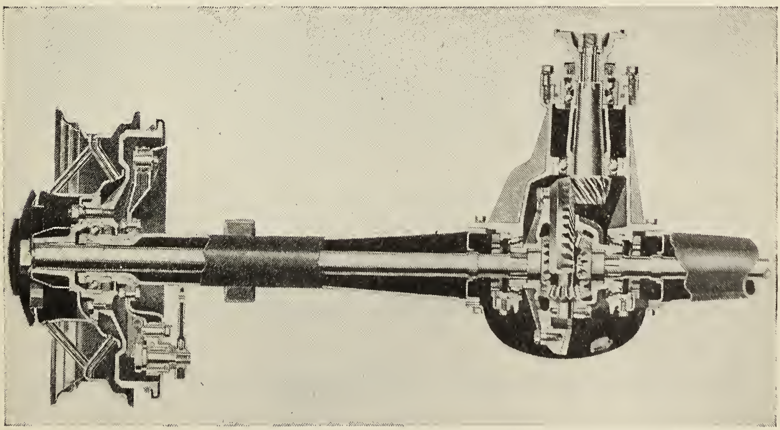


FIG. 17–20. The drive shaft connects the transmission gears with the differential. (*Courtesy Cadillac Motor Car Co.*)

The drive shaft connects the transmission gears with the *differential.* [See Fig. 17–20.] This set of gears is housed in the center of the rear axle. The differential permits one rear wheel to turn faster than the opposite one when the car is rounding a curve or a corner. Otherwise the tires would slide and wear away rapidly.

***380. What may we expect of cars of the future?** Naturally, no one can tell what tomorrow will bring. We may be fairly certain, however, that in normal times the streamlining of all cars will continue. It is probable, too, that the Diesel engine may replace the gasoline engine in pleasure cars, as it has already begun to do on busses and trucks.

The Diesel engine differs little from the gas engine. During the first of the four strokes, air is pushed into the cylinder. It is then compressed during the second stroke to a pressure of about 450 pounds per square inch. Such compression heats the air very hot. In fact, it is hot enough to kindle the hot oil vapors which are forced into the cylinder just before the beginning of the third stroke. For that reason no spark is needed. After the kindling and exploding of the fuel vapors during the third stroke, the exhaust valve opens to permit the waste gases to escape during the fourth stroke.

Diesel engines are economical to operate. They are more efficient than the gas engine and they use cheaper fuel. They are often used in place of steam engines for generating electricity.

The *Zephyr* is an all-metal railroad train built of stainless steel. A 600-horsepower Diesel engine is used in this train to generate the electricity that is needed to drive this train at a speed of 100 miles per hour on its run between Chicago and Denver.

**381. Man learns to fly.** In our eagerness for speed and more speed, we seem to walk on leaden feet. Old Dobbin jogs at a snail's pace. Our fastest cars and speediest trains are plodding tortoises. We admire the speed of the wing-footed

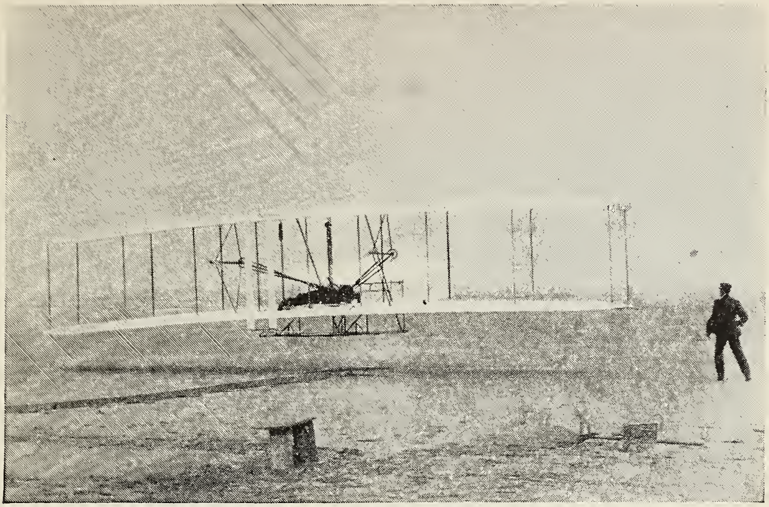


Fig. 17–21. In this plane the Wright brothers made their historic flight in 1903. (*Courtesy Wright Aeronautical Corp.*)

Mercury so much that we are likely to forget about his disregard for the property rights of others.

Man has made many attempts to learn to fly. In all countries, someone has tried to emulate Daedalus (dĕd′*ȧ*·l*ŭ*s) and Icarus (ĭk′*ȧ*·r*ŭ*s) and fit himself with wings. In too many cases, the wings proved to be of wax, like those of Icarus, and they melted when man flew too high.

At first, men attempted to use gliders. Two brothers, Wilbur and Orville Wright, sons of Bishop Milton Wright, of Dayton, Ohio, performed one experiment after another. They watched the birds in their flight and tried to copy them. Then, in December, 1903, Orville Wright made the first flight ever made in a power-driven airplane. Of the four flights made at Kitty Hawk, North Carolina, on that morning, the longest was 59 seconds, and the distance was 852 feet. [See Fig. 17–21.] Those short flights marked the beginning of the "flying age" for man.

**382. What keeps an airplane aloft?** A balloon floats because the weight of the balloon and its contents is less than

the weight of the air which the balloon displaces. That is an illustration of Archimedes' principle, but the airplane is different. It is a heavier-than-air machine. Hence it is impossible for it to float. Two things help to keep an airplane aloft, but only if the airplane is in rapid motion.

*a*) As the engine drives the plane forward at a high speed, the air reacts against the wings of the plane. It behaves just as if the plane were standing still and the wind were blowing against its wings with the same velocity that the plane is driven forward. The plane is not pushed backward by the wind, but the force of the wind is split up into two separate forces, just as the wind against the sail of a sailboat is split into two forces, one of which drives the boat forward and the other of which tips it sidewise. One of the forces, called the *drift,* tends to push the plane backward. The other force, called the *lift,* exerts an upward push upon the plane. The forward speed of the plane must be great enough to produce a lift force that is equal to the weight of the plane and its load.

*b*) As the plane is driven forward, a partial vacuum is produced above the airplane wings. The partial vacuum thus created decreases the downward air pressure upon the plane. The unbalanced air pressure beneath the plane helps decidedly in pushing the plane upward. Before an airplane can take off, or rise from the ground, it must taxi fast enough so that the sum of the two upward pushing forces will become equal to the weight of the plane.

**383. What are the parts of an airplane?** Of course there must be an engine to drive the plane forward. It may have several hundred horsepower. The wings are needed to support the plane. The *fuselage* (fū′zĕ·lĭj) is that streamlined portion of the plane which carries the passengers, the cargo, and possibly the power plant. There are several other parts.

*a*) *The vertical fin.* At the rear of the plane we find the vertical fin which prevents the plane from being driven about by gusts of air. It increases the stability of the plane. It is not unlike the tail fin of a fish.

*b*) *The rudder.* Attached at the rear of the fin is the rudder. It is not unlike the rudder of a boat, and it is used for the same purpose, to turn the nose of the plane to the left or the right.

*c*) *The stabilizer and elevators.* At the rear of the fuselage there is a horizontal tail plane used to keep the whole plane on an even keel. It is called a stabilizer. Attached to the rear end of the stabilizer, we have the elevators. They are so hinged that they can be turned slightly downward by the control stick when the pilot wishes to turn the nose of the plane downward, or they may be tilted upward if one wishes to turn the nose of the plane upward. They are tilted upward, for example, just as the plane takes off and rises from the ground.

*d*) *The ailerons.* You have seen roads banked at curves to prevent cars that are rounding the curve at high speed from overturning or sideslipping. As an airplane rounds a curve, it will skid unless its wings are turned up on edge so they can be held by the reaction of the air against their broad under surfaces. To accomplish this, ailerons are used. They consist of small planes, hinged to the rear edges of the wings. If an aviator wishes to make a right turn, he uses a control which tips the right aileron upward and the left aileron downward. The increased air pressure above the right wing pushes that wing downward, and the increased pressure below the left wing pushes that wing upward. The combined efforts of the two ailerons thus tilt or bank the plane so that it rides around the curve safely.

**384. Why is the airplane important?** The present generation has seen the airplane rise to vast military and commercial importance. Aviation schools have sprung up over the country, not only for teaching men how to fly, but also for teaching them the principles of aviation engineering.

Transcontinental airplane lines run their planes on regular schedule, carrying mail, passengers, and even some freight. The time now needed to carry mail from New York to San

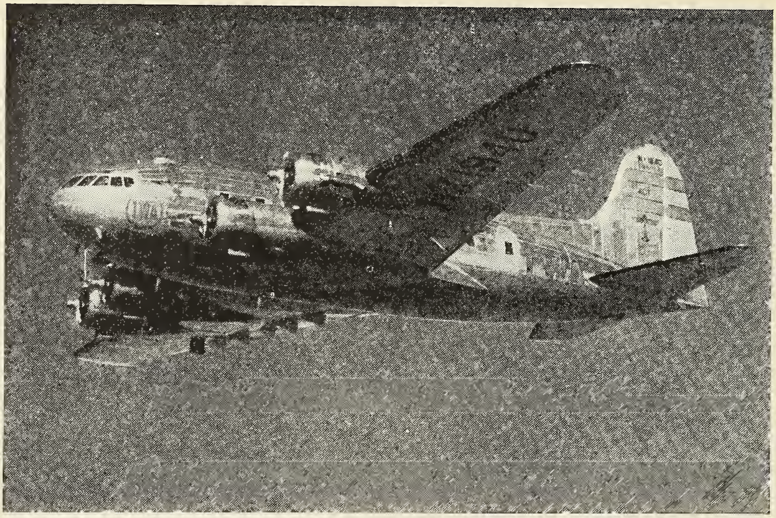
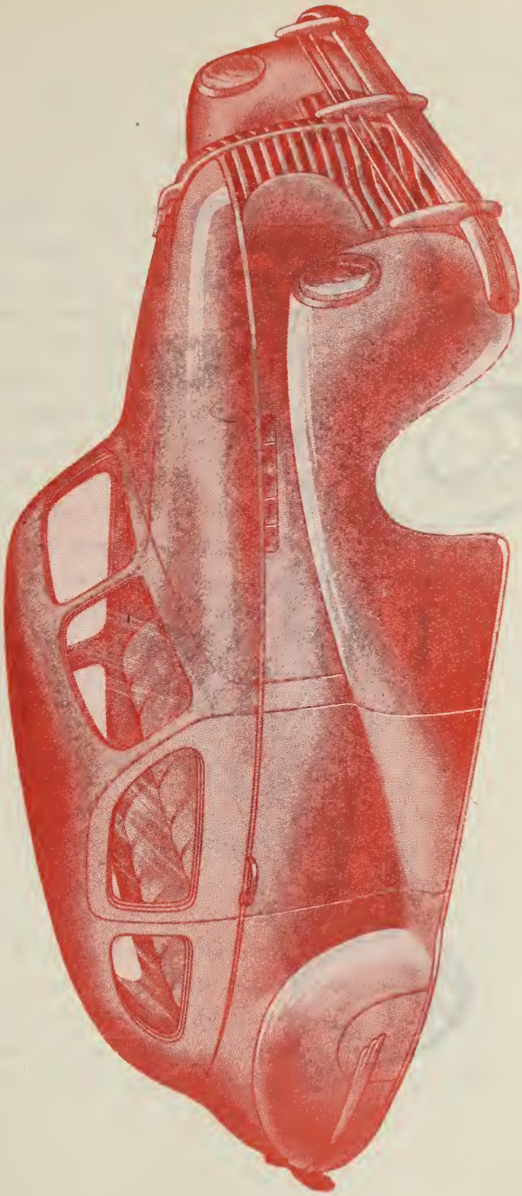


FIG. 17–22. One of the large transcontinental planes used for passenger flights across the United States. The huge plane is powered with four motors. (*Courtesy Transcontinental and Western Air, Inc.*)

Francisco is only one day, or possibly less. A man can eat his breakfast in New York and his dinner in Los Angeles. Passengers are carried millions of miles in relative safety. Airplanes are used to range our forests to protect them against dangerous fires. The airplane is sometimes used by farmers to spray fields with poison to check the ravages of destructive insects.

Man has reached an altitude of about 8.5 miles in a heavier-than-air craft. Racing planes have attained speeds of 469 miles per hour. Flights have been made across the Atlantic Ocean and the Pacific, and from Moscow to Canada by flying over the North Pole. [See Fig. 17–22.] Military planes find use as combat planes, for laying down smoke screens, for scouting the enemy, and for bombing purposes. They have been used, too, for landing men by parachutes behind the enemy lines. Such airplane carriers as the *Lexington* and the *Saratoga* can carry several score of planes each, and their decks are roomy enough to permit planes to land upon them



Hold up to light for X-ray effect. Then turn page for explanation and detail
(Rights and lefts are reversed)

The modern automobile, with its streamlining and its bright finish, is a thing of beauty. It is easy to see how it looks on the outside, but how would it look on the inside?

If you could peer through the steel body of an automobile as easily as you can through its windshield, you would see a complicated structure. Under the hood is a power plant which may be as powerful as 100 horses. You could see the fan which cools the engine, the filter which removes the dust from the air before it goes into the carburetor, and the pipe which brings the gasoline from the tank to the engine. Possibly you would see the gears turning in grease which helps to keep them silent and to lessen wear. You would see wires and bands and pipes, and the drive shaft which connects with the axle and wheels to make the automobile move. The complex mass of machinery rests on a sturdy metal frame, which in turn rests on the axles and wheels.

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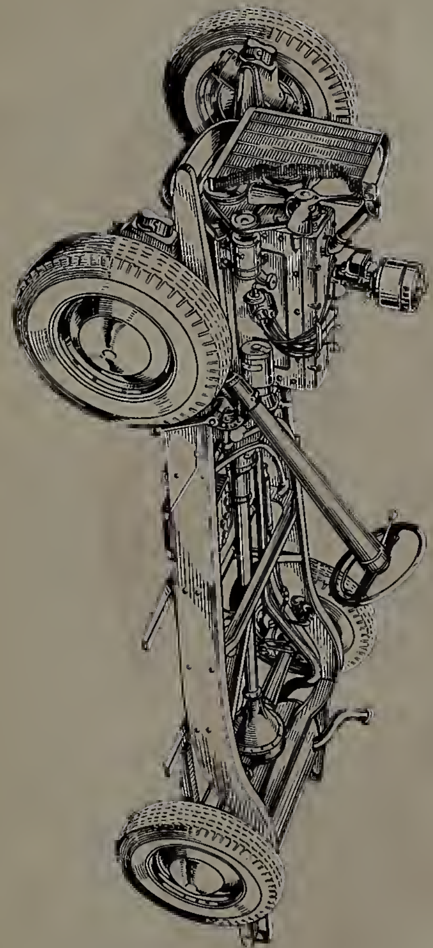
Open this double page out fully, close the book, and turn it over, back face up. With the right hand, hold the book up so that the light shines through the part of the page outside the book. You can then see through the exterior of the automobile to the inner parts. Now turn the book around and hold it in your left hand, the same way. You can now see the inner parts of the automobile with the body showing through. The resulting X-ray effect gives you a relationship between the inner parts and the exterior which would otherwise be difficult to see.



or to take off from the surface of the decks. Planes have been used, too, on important errands of mercy. They may carry medicine to a person stranded in some out-of-the-way place, to supply him with food and clothing, or possibly to effect a rescue.

## QUESTIONS

1. Why is it easier to float in sea water than it is in fresh water?
2. Battleships are covered with steel plates that are from 10 to 18 inches in thickness. How is it that they can float?
3. Would a battleship sink deeper in the waters of Lake Erie than in the Atlantic Ocean? Give a reason for your answer.
4. A boy digging a hole in the ground unearths a stone which he cannot lift. Will it help him if he fills the hole with water? Give a reason for your answer.
5. Gasoline is only about 0.7 as dense as water. Do you think you could float in a tank of gasoline?
6. Much energy is obtained from water power. What is the real source of such energy?
7. Balsa wood is only about half as dense as cork. For what purposes can balsa wood be used?
8. Water one foot deep exerts a pressure of 0.433 pounds per square inch. What is the water pressure at the base of Boulder Dam, if the water is 726 feet deep?
9. Why must dams be made so much thicker at the bottom than they are at the top?
10. Why is the wheel so important an invention?
11. What part did James Watt play in the invention of the steam engine?
12. What contribution to travel and transportation did Stephenson make?
13. What was the contribution of Robert Fulton? of the Wright brothers?
14. Why may the steam engine be called an external-combustion engine?
15. For what purpose is a cam used in machines?

16. What factors have helped to increase the speed of trains?

17. What advantages does the steam turbine have over the older type of steam engine?

18. Can you see any reason for speaking of the propeller of the *Queen Mary* or the *Queen Elizabeth* as a screw?

19. What principle is involved in the operation of a gas engine?

20. What is the purpose of the carburetor of a gas engine?

21. What happens during each of the four strokes in the operation of a gas engine?

22. What is the meaning of the term *inertia?*

23. What is the purpose of the flywheel on the crankshaft of a gas engine?

24. Why has the automobile industry grown to such giant proportions during the last twenty-five years?

25. For what purpose is the clutch used on an automobile?

26. For what purposes does the driver of a car use the clutch?

27. Why is a small electric generator needed for an automobile?

28. What is the purpose of the electric motor on an automobile?

29. What is the purpose of the ammeter on the instrument panel of a car?

30. Why is a thermometer or a heat indicator placed on the instrument panel of the modern car?

31. What other instruments are placed on the instrument panel of the car where they can easily be seen by the driver?

32. What advantages does the Diesel engine have over the gasoline engine?

33. Do you think the airplane would be practical without the gasoline engine?

34. What are the important parts of an airplane, and what is the purpose of each one?

## *Some things for you to do*

1. Look up Darius Green and make a report on his method of flying.

2. Write a 250-word paper on the subject of what the invention of the gas engine has meant to rapid transportation.

3. Make some silhouettes of different types of planes.

# Man Makes His World Smaller by New Ways of Communication

In colonial days, men had few neighbors. Now there are more than 130,000,000 persons in the United States, and the most distant neighbors are actually closer together than New York and Philadelphia were in those days. A messenger had to ride posthaste to carry a message or a letter the 90 miles between the two cities in less than two days. Now a letter goes by train in an hour and a half, and an airmail letter may be carried from New York to San Francisco in 12 hours.

If a New Yorker is really in a hurry to communicate with a friend in San Francisco, he may send a telegram, or he may use that marvelous modern miracle, the telephone, which permits him to carry on a conversation across the continent almost as easily as if the other person were sitting in his own living room. Or anyone may talk from New York to London, if he is willing to spend about twenty dollars. From the

central station of the American Telephone and Telegraph Company, his voice travels by wire to Rocky Point, Long Island. There it is amplified 2,000,000,000 times, until its energy becomes equal to 70 horsepower. With his 70-horsepower voice, he shouts across the Atlantic by wireless. At Wroughton, England, where his voice is received, it is amplified and sent on by wire to London.

In this unit we shall learn some of the methods which man uses to communicate with his fellow men. We shall find out something about the audion tube, and learn how it is used in radio work. We shall get a glimpse of television, which seems to be just coming around the corner as a commercial success. In the progress of science we find a fast-changing scene. Some of the things that were new only a short time ago are now almost obsolete, and the new of today will become the commonplace of tomorrow.

## *Think about these!*

1. By what three methods can you send a message from New York to Washington in a few minutes?
2. How long does it take for the visual image to fade out after you have stopped looking at an object?

## *Words for this chapter*

**Rarefied.** Made less dense.

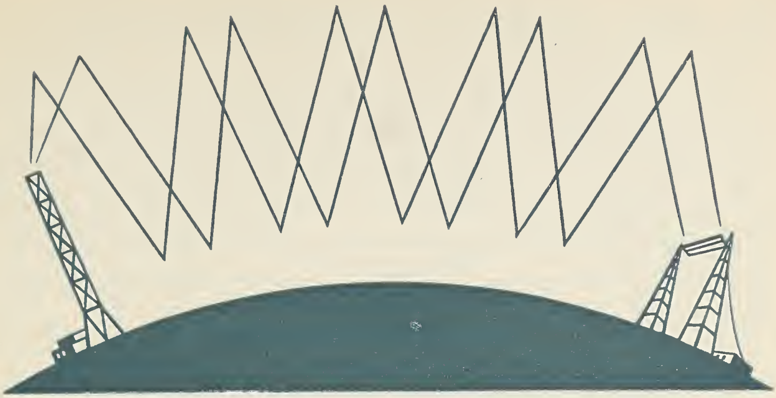
**Ether.** An imaginary, weightless fluid through which heat, light, and radio waves are thought to be transmitted.

**Audion.** A vacuum tube used for many purposes in radio work.

**Kilocycles.** One thousand cycles.

**Oscillating.** Vibrating to and fro.

**Condensations.** As used here, those parts of a sound wave in which the air is compressed or condensed.



CHAPTER 18 ———————— UNIT 9

# *How Can Speech and Pictures Be Sent Over Wires and Through the Air?*

**385. Why does man use speech?** We often find need to communicate with our neighbors. Nearly all animals make sounds, but man seems to be the only animal that uses speech to communicate his thoughts to others. There are, however, many cases on record which cause us to believe that many of the lower animals do have some means of communicating certain needs, wishes, or warnings to other individuals of their kind and possibly to other animals. We must confess, though, that the language they use is unknown to man.

**386. Our American ancestors had few neighbors.** It is said of the early American colonists that no one could see his neighbor without a telescope, or hear him unless he fired a gun. The human voice may carry for a mile, if the circumstances are favorable. For more distant communication, man may use a wigwag system, or flash signals by means of a

mirror. Man may send letters to carry his communications.

Are you not thrilled by Longfellow's description of the ride of Paul Revere? Signaled by the lanterns which hung from the tower of old North Church, we picture Revere as he races madly from Boston to Lexington, where he paused to awaken Samuel Adams and John Hancock and warn them of the approach of the British. Then on he speeds to Concord to the spot where

> The embattled farmers stood,
> And fired the shot heard round the world.

Today the warning would take less than a minute. We would give Samuel Adams a ring on the telephone, and tell him that the enemy were on the march. No one would ever write any poetry about such a telephone call, but the fact remains that the telephone is a marvel of efficiency. But the telephone is only one of the instruments which modern man uses to communicate his thoughts to others.

**387. How old is the telegraph?** It was near the end of Andrew Jackson's second term as President that Samuel F. B. Morse gave a public demonstration of the electric telegraph which he had invented. Many of our inventions are named from one or more Greek words. For example, the *telegraph* takes its name from two Greek words, *tele,* which means *far off,* or *end* and *graphein,* which means *to write.* The operator closes a circuit at one end of the line, and the message which he sends is either written or tapped out at the far end of the line. The early telegraphs wrote the signals on a strip of paper, but the modern telegraph raps out sound signals which are intelligible to the listening operator.

It was not until 1843, however, that Congress appropriated $30,000 to build a telegraph line from Baltimore to Washington. The first message, "What hath God wrought!" was sent from Washington to Baltimore on May 24, 1844. The first *official* message was the announcement of the nomination of James K. Polk for the presidency.

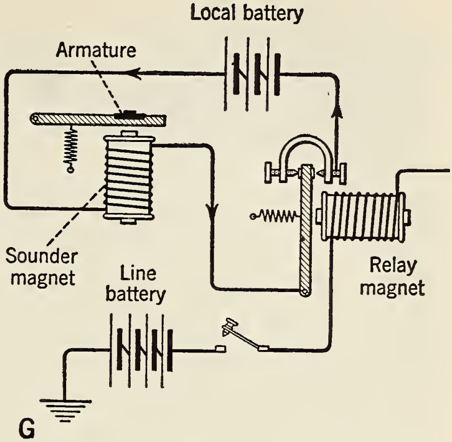



FIG. 18–1. In a local telegraph system the relay acts as a circuit closer. The local battery then energizes the electromagnet of the sounder and causes it to "click out" the signals so that they will be audible.

**388. Of what parts does a telegraph system consist?** If we study the wiring diagram of Figure 18–1, we notice that there are several parts to a telegraph system.

*a*) *The line wires.* Copper is a better conductor of electricity than iron, but because iron wire is cheaper, it is often used for the line wires of a telegraph system. Such wires are strung on poles, placed about 60 feet apart. Glass insulators are used to keep the wires from touching the poles. Thus they prevent loss of current to the ground. In cities such wires are placed in a conduit and buried beneath the streets.

*b*) *The batteries.* In the early days, voltaic cells were used to supply the current for the line wires, and also for the local battery which operates the mechanism known as the *sounder.* Now a storage battery or some other source of direct current is used.

*c*) *The key.* The switch key is a circuit closer, much like the push button for your doorbell. The contact points, however, are coated with tungsten or some other metal which does not tarnish. Hence the operator is always assured of a good contact when he presses the key to send a message. [See Fig. 18–2.]

The kind of signal an operator sends depends upon the length of time he holds the key after pressing it down. He

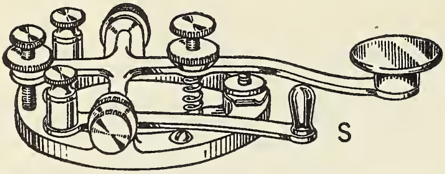



FIG. 18–2. The telegraph key enables the operator to open and to close the circuit.

may make a short signal called a *dot,* or a longer signal called a *dash.* The alphabet of the Morse Code consists of a series of dots and dashes, each combination representing certain letters. When an operator is receiving a message, he either holds down his own key as he listens, or he closes the circuit with a sliding switch key, marked S in Figure 18–2.

*d*) *The sounder.* Mounted upon a board of the sounder we find an electromagnet. A light lever, usually made of aluminum, is pivoted in a metal frame in such a manner that it can move up and down between, or a little above, the poles of the electromagnet. Attached to the lever is a piece of soft iron. [See Fig. 18–3.]

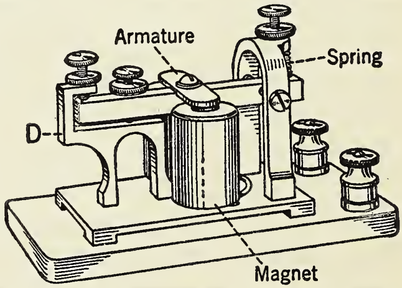
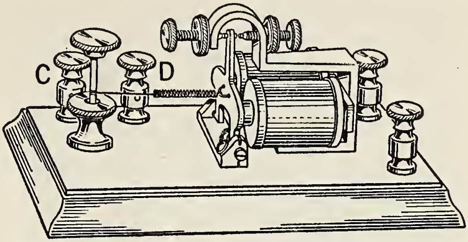



FIG. 18–3. When the magnet is energized, the armature is attracted to it. Thus it strikes the brass piece at D and causes a signal. The spring pushes it back upward when the circuit is broken.

When the operator presses his key, and thus closes the circuit, current flows through the coils of the electromagnet, thus magnetizing them enough to attract the armature and pull it toward the electromagnet. As this happens, a small setscrew in the end of the lever strikes the metal frame of the sounder with a sharp click. As soon as the circuit is broken, the magnet loses its magnetism, and a spring at the opposite end of the lever pushes the armature upward again, away from the magnet. Then it is ready for the next signal.

FIG. 18–4. When the sounder signals are weak, a relay is used to close the circuit through a local battery.




*e*) *The relay.* Look at Figure 18–4. You notice that the armature of the electromagnet of the relay is pivoted at one end of the electromagnet, and that it stands in a vertical position. The relay is connected with the line wires of the telegraph circuit. It has a powerful magnet which is used to open and close the circuit.

The *galvanized* iron wires used for the line do not have a high resistance, but many miles of such wire may offer so much resistance that the current will become too feeble to make the sounder click loud enough to be heard distinctly. It is strong enough, however, to move the armature of the relay, which opens and closes the circuit through the sounder and a local battery. The line battery operates the relay. The local battery operates the sounder in response to the key worked by the operator at the far end of the line, who is sending the message.

**389. What is the Morse Code?** A series of dots and dashes to represent the various letters of the alphabet was used by Morse. For example, the letter A is represented by a dot and a dash as follows: (· —), the letter E by a dot (·), the letter O by three dashes (— — —), and the letter S by three dots, (· · ·). The SOS, which means " Come quick, distress! " is represented by three dots, three dashes, and then three dots. Each letter has its own combination of dots and dashes, which the operator must learn. He learns to read by ear, by listening to the clicking of the sounder. [See Fig. 18–5.]

**390. What is the teletype?** Messages sent by the Morse code are not so commonly used as they were at one time. An

FIG. 18–5. Samuel F. B. Morse (1791–1872) was an American inventor. He was a Professor of Design at New York University, but gave much attention to chemistry and electricity. He is the inventor of the electric telegraph.

operator now uses a machine similar to a typewriter. At the far end of the line a similar machine writes the story or message in type which anyone can read. Of course they can be recorded at a large number of stations at the same time. Police reports, news stories, and telegraph messages are often sent by the *teletype* system.

**391. A man with perseverance.** Cyrus W. Field, an American inventor, conceived the idea of laying a cable upon the ocean bottom between Newfoundland and Ireland, for the purpose of transmitting messages between Europe and America. Try to imagine the difficulty of such an undertaking, for the distance is 1600 miles. The copper wires inside the cable, which were to be used to carry the electric current, were reinforced with steel wires to strengthen the cable. The cable had to be insulated and also waterproofed. Its weight was nearly 500 tons.

The first effort ended in failure because the cable broke when it was being laid, before the vessel paying out the cable had covered one-fourth of the distance. A new cable was

made and laid successfully. It worked well for a time, and then it stopped working. A third cable, larger than the other ones, was then made, but it broke in midocean. Field was a persistent man, as successful men must be. He appealed to his financial backers. They answered his appeal, and a new cable was made and laid successfully in the year 1866.

The broken cable was too valuable to be lost. Men grappled for the broken ends of the lost cable, found them, spliced and repaired the broken ends, and laid the cable successfully. Field crossed and recrossed the Atlantic Ocean; he suffered many disappointments; he met with financial losses; in the end, his persistence was rewarded. Since 1866 we have been in daily communication with our English cousins on the opposite side of the Atlantic ocean by means of the submarine cable.

**392. Who invented the telephone?** If a considerable number of persons happen to be present, anyone asking who invented almost any device is courting trouble. Someone might claim that the Englishman Wheatstone used the name *telephone* to describe the transmission of sound by wooden rods. Another person might mention that Page, of Salem, Massachusetts, as early as 1837, noticed that an iron rod will emit sounds, if it is suddenly magnetized and then demagnetized. Someone else might tell you that the Frenchman Berseul, in 1854, conceived the idea of the principle of the telephone, but did not put it into practice. Still another person in the group might claim that the German Ries was able to transmit sounds some distance by means of a device which he called a *telephone*. A man from Dartmouth College might credit Professor Dolbear with the invention of the telephone, and a graduate from Oberlin College might propose the name of Elisha Gray for the honor. The majority of persons present would doubtless name Alexander Graham Bell as the inventor. [See Fig. 18–6.]

The purpose of the foregoing discussion is not to stir up dissension, but merely to show that the principles underlying

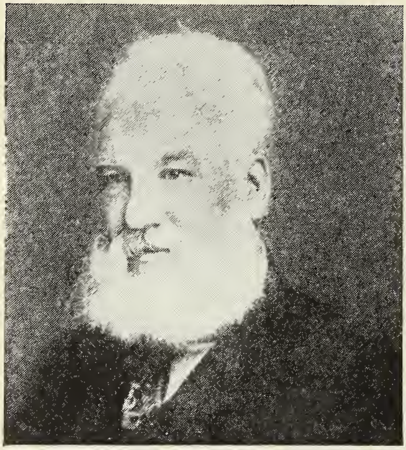


FIG. 18–6. Alexander Graham Bell was an American inventor. He became interested in his father's system of instructing the deaf and dumb. In 1872 he became professor of vocal physiology in Boston University. This work led to his interest in the speaking telephone, for which he received a patent in 1876. His interest in the education of deaf-mutes continued after his invention of the telephone. (*Courtesy Bell Telephone Laboratories*)

almost any invention have been at least partially understood and worked upon by a number of different persons. As a rule, that man who makes the invention a practical success is the person whom most persons consider the real inventor. Progress in scientific research really means that the work of one scientist is added to that of those who preceded him.

**393. How does the simple telephone work?** What was formerly called the simple telephone, we now call the telephone receiver. Look at Figure 18–7. We see that the tele-

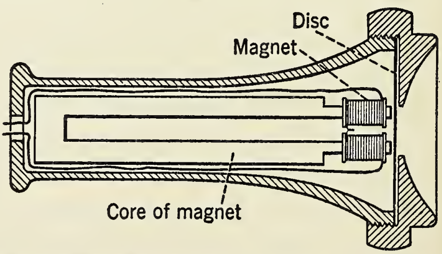
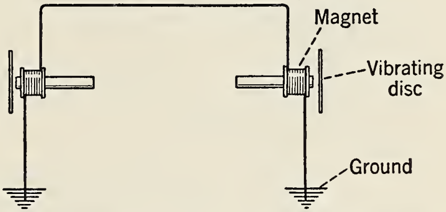



FIG. 18–7. The telephone receiver is often called the simple telephone. It has a permanent magnet, which is so wound that it can also become an electromagnet.

phone receiver consists of a permanent magnet with a coil of fine, insulated wire wound around at least one pole of the magnet. (If the magnet is horseshoe-shaped, there is a coil of wire wound on each pole.) Thus we have both a *permanent magnet and an electromagnet combined.* An iron diaphragm, or vibrating disc, is so placed in front of the end of

the magnet that it may change the strength of the magnet, and thus produce a current in the coil, whenever the iron diaphragm moves nearer to the end of the magnet, or swings farther from it. When current flows through the coil or coils, the electromagnet may increase the strength of the permanent magnet. If we vary the strength of the permanent magnet, we can set up a current of electricity in the insulated coil of wire.

FIG. 18–8. Two simple telephone receivers can be used for communicating short distances.




Suppose we connect two receivers as shown in Figure 18–8. If one person speaks into one of the receivers, the sound waves from his voice alternately condense, or crowd together, those air particles immediately in front of the diaphragm of that receiver, and then permit them to expand again, or to become *rarefied.* A condensation of the air particles will push the iron diaphragm closer to the end of a magnet, and then when the air expands or is rarefied, the diaphragm will spring back again. As it moves forward and backward, it changes the strength of the permanent magnet and sets up a current of varying strength in the coils. This current varies in strength with the sound waves of the voice. At the transmitter end of the telephone, *voice waves are changed into electrical energy.*

The current of varying strength thus set up by the voice is carried through the wires to the receiver at the opposite end of the line. There it changes the strength of the permanent magnet of that receiver, and causes the diaphragm to vibrate in the same manner as that of the transmitter. In such manner, *the receiver changes the electrical energy which it receives back into sound waves.* By means of two simple

receivers, connected as in Figure 18–8, two persons may talk with each other for a distance of a mile or more.

**394. How has the transmitter been improved?** To carry on a conversation with some person many miles away, a sensitive transmitter is necessary. If we look at Figure 18–9,

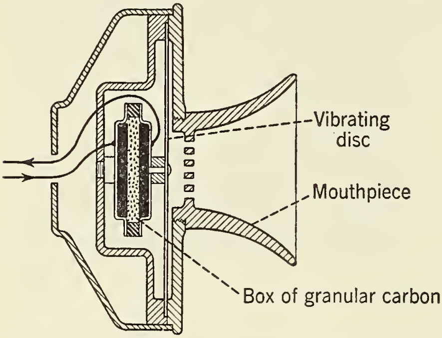



FIG. 18–9. The modern transmitter is a very sensitive device. It converts sound waves into electrical waves.

we see that the modern transmitter has a small box filled with particles of carbon. The back of the box is a carbon plate which is connected in series with a battery and one end of the inner coil of a small *induction coil.* The other end of this inner coil is connected with the diaphragm of the transmitter, as shown by the heavy line of Figure 18–10. The vibrating diaphragm is connected with the front plate of the box filled with carbon particles. The sides of the box are insulated.

As the diaphragm is thrown into vibration by the sound waves of the voice, the carbon particles in the box are com-

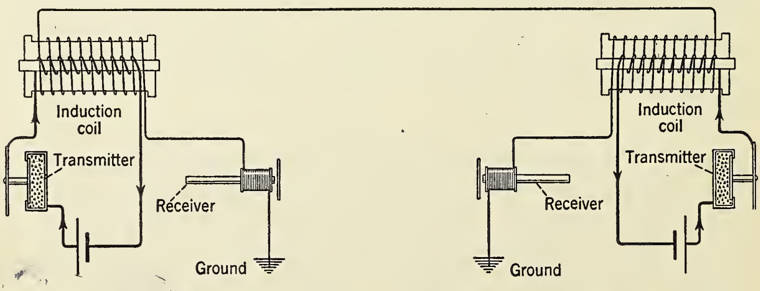



FIG. 18–10. This diagram shows the arrangement of a local telephone system.

pressed and released alternately by the condensations and rarefactions of the voice waves. Such a variation in pressure changes the resistance of the carbon particles, and thus causes the current flowing through the inner coil of the induction coil to vary in strength. The inner coil of the induction coil is called the *primary coil,* and the outer coil is called the *secondary coil.*

As the current in the primary coil varies, the current in the secondary coil will also vary. Its voltage is raised, too. Such a variation in the current of the secondary coil causes a similar variation in the coils of the magnet of the receiver, with which the secondary coil is connected. The varying current in the receiver causes the diaphragm to vibrate and cause sound waves, almost identical with those spoken into the transmitter. The transmitter changes sound waves into electrical energy, and the electrical energy which travels to the receiver is there changed into sound waves. [See Fig. 18–11.]

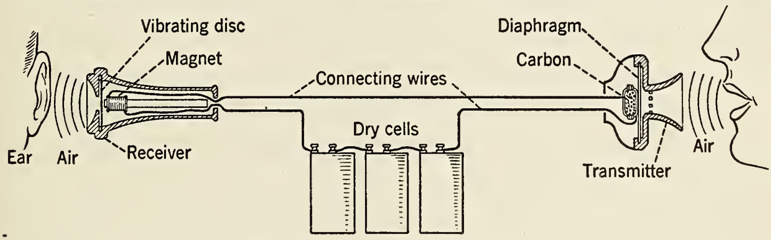



FIG. 18–11. Voice waves vary the electric current and cause similar sound waves at the receiver end.

**395. Who invented wireless communication?** Just as there are several names prominent in the invention of the telephone, so we find that several persons are more or less responsible for our present methods of communicating without wires. As early as 1873, James Clerk-Maxwell proposed the belief that light and electricity both have the same nature, and that both travel at the same speed through the *ether.* The so-called ether was first mentioned by Huygens in 1678 when he set forth the theory that light travels in waves.

Huygens invented the ether out of his own imagination, since he believed that there must be some material between heavenly bodies and the earth to transmit light waves.

You may think of the so-called ether as a fluid which fills all space. It is so thin that it creeps between the molecules of all matter and even fills the best vacuum. It cannot be confined or weighed. It offers no resistance by friction to the planets which revolve around the sun or to the stars which move through space. Radiant heat, light, and radio waves are all supposed to be transmitted by the ether.

Maxwell predicted the presence of the ether waves that now affect our wireless sets. In 1888, Heinrich Hertz detected such waves and measured their length. He also showed that they may be reflected and refracted just like light waves. They are called Hertzian waves.

In 1894 Guglielmo Marconi invented a *coherer* for detecting wireless signals. He also developed the wireless telegraph. Here, too, because Marconi made practical the sending of wireless signals, most persons would tell you that Marconi is the inventor of wireless.

Many other persons have done a great amount of research work in the development of radio communication as we know it today. We mention J. J. Thomson, who developed the electron theory, and Lee De Forest, who did so much toward the perfection of the vacuum tube, or what is often called the *audion tube*, which may be considered the heart of both the sending and the receiving sets in radio.

**396. What three things are needed?** In ordinary hearing, we need something to throw matter into vibration and produce sound waves. We need the air, or some other medium, to carry those waves to us. And, of great importance, we must have an ear which is sensitive to the sound waves it receives. In the case of sight, we must have light waves, some way of getting them to us, and an eye to see them. In our study of communication by telephone, we learned that a *transmitter* is necessary, some wires to carry the current,

and a receiver. Three things are needed, too, in wireless communication.

*a*) Some device must be used to generate the ether waves. Several methods have been used, but the audion tube is the most common.

*b*) To transmit the ether waves, or the Hertzian waves we must depend upon the ether to carry them to us.

*c*) There must be some device which is sensitive to such ether waves to enable us to detect them. Our receiving sets have several audion tubes which receive such waves and translate them into sound waves for us.

**397. Some ether waves.** The effects produced by ether waves are numerous. Some different types of wave follow.

*a*) *Heat waves.* Considerable energy from the sun comes to us as heat waves. They are rather short ether waves.

*b*) *Light waves.* These waves, too, come to us from the sun in the form of ether waves which are still shorter than heat waves. They are so short that it would take at least 200 of them laid end to end to make a line as long as the thickness of an average sheet of paper. The red waves are the longest light waves, and the violet are the shortest ones.

*c*) *Ultraviolet waves.* Ultraviolet waves are too short even to affect the optic nerve of the eye. They are responsible for the tan we get in summer, and they cause a photographic plate to be darkened rapidly. They are only about one-thirtieth as long as those waves which we know as violet light.

*d*) *The X rays.* It would probably take about 300,000,000 X rays to make a line one inch long. They are so short that they are scattered by a surface so smooth that its irregularities do not vary more than one-millionth of an inch. As you know, the X rays penetrate flesh and many other things that are opaque to light.

*e*) *Cosmic rays.* These rays, which seem to come to the earth from outside space, are believed to be not more than one-five-hundredth as long as the shortest of the X rays.

*f) Radio waves.* These are the waves that travel through the ether, come through the walls of our houses, and affect our radio sets. They are long waves, when compared to the other ether waves we have studied. Some of them are only a few meters long, and some of them are more than 10,000 meters in length. We cannot see them, hear them, or detect their presence by any one of our senses, but our receiving set picks them up and translates them into speech or music.

**398. How are wave lengths and kilocycles related?** You read in your papers, or you hear the radio announcer say, that a certain station is broadcasting on a frequency of 1000 *kilocycles.* To say that that particular station is using a 300-meter wave length means the same thing. The metric system is used in measuring the length of ether waves.

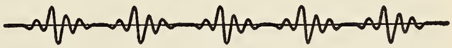
Both light and electricity travel at the speed of 300,000,000 meters per second. Suppose we have an object which is *oscillating,* or vibrating, just 1,000,000 times per second, or at a frequency of 1,000,000 cycles per second. There are 1000 cycles in one kilocycle. Hence, 1,000,000 cycles equal 1000 kilocycles.

If an object vibrates 1,000,000 times per second, and its waves travel 300,000,000 meters per second, then the first wave will be 300 meters away by the time the second wave has started. The first wave will be 600 meters distant by the time the third wave has started, and the first wave will be 300,000,000 meters away when the millionth wave has started. That means 1,000,000 waves spread out over a distance of 300,000,000 meters. But, 300,000,000 divided by 1,000,000 equals 300. Each wave, therefore, is 300 meters long. A station broadcasting on a frequency of 750 kilocycles sends out ether waves 400 meters long, or it has a wave length of 400 meters.

**399. How are radio waves produced?** It was Hertz who discovered that an electric spark oscillates, or vibrates, rapidly, and for that reason gives rise to ether waves. In the early stages of radio work, a spark coil was used to produce

radio waves. A telegraph key in the circuit with the coil was used to control the shower of sparks from the coil and thus produce the dots and dashes needed for sending messages. The so-called *damped* waves produced by an electric spark are not suitable for broadcasting speech or music, although you may hear a noise or signal in your radio when your electric refrigerator or your oil burner goes on or off. [See Fig. 18–12.]

FIG. 18–12. Damped waves produce signals.



***400. How is the voice put on the air?** Look at the diagram of Figure 18–13. In broadcasting, several vacuum tubes are used. One of them is an *oscillator*. As it vibrates, it produces high-frequency ether waves, which are *un-*

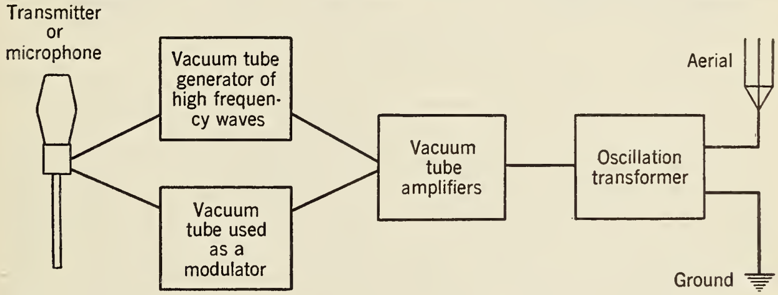



FIG. 18–13. This diagram shows how the voice is put on the air.

*damped*, or *continuous, waves*. They form what is called a *carrier wave*. A continuous carrier wave is used for broadcasting, and it is modulated by the voice or by music. [See Fig. 18–14 A.]

A second vacuum tube is used as a *modulator* to blend the voice wave with the carrier wave. [See Fig. 18–14 B.] The microphone differs little from the transmitter of a modern telephone. As one speaks into it, the condensations and rarefactions set up in the air by his voice cause corresponding variations in the modulating tube.

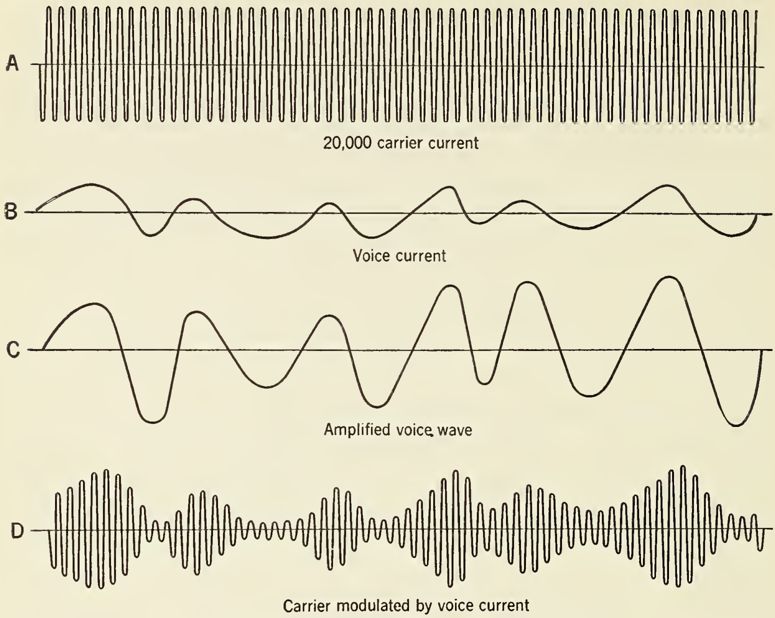



FIG. 18–14. This diagram shows the carrier wave, or current, the voice current, and the carrier wave modulated by the voice wave.

A bank of vacuum tubes is used to amplify the carrier wave which has been modulated by the voice wave. [See Fig. 18–14 C.] This amplified wave then goes through an oscillation transformer to the aerial wires, or the *antennae.* The vacuum tubes used in broadcasting do not differ in principle from those used in your receiving set, but they are much larger. Some of them have an output equal to 70 horsepower.

**401. How are radio waves received?** Marconi invented a coherer to receive wireless signals. It was satisfactory for use in wireless telegraphy, but not for receiving speech or music. It is now obsolete. [See Fig. 18–15.]

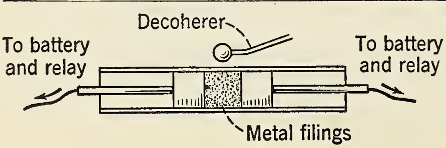
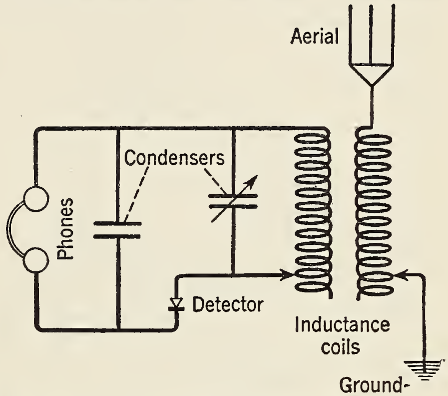



FIG. 18–15. Marconi's coherer was a simple device.

In the early days of radio a *crystal detector* was used for radio reception. Many amateurs made their own sets, using a crystal of *galena* (an ore of lead), or some other crystal, as a detector. A set of earphones, a couple of *condensers*, which vary the electrical capacity of the circuit, and the antenna-ground system, were all connected in the circuit with the crystal detector. [See Fig. 18–16.] Such a receiving set gave

FIG. 18–16. Possibly your father made his own receiving set by the use of a crystal detector. Sometimes he got fairly good reception.




fair results. The crystal permitted electricity to flow through it readily in one direction, but it did not permit it to flow freely in the opposite direction. That property of the crystal made it a detector of radio waves. It picked up just half of the modulated carrier and voice wave. [See Fig. 18–17.]

The next important step in radio reception came as a result of the invention of the *vacuum tube*. Not only does this tube

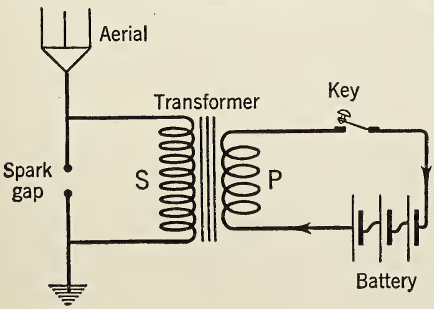



FIG. 18–17. A simple device for sending out wireless signals.

accomplish the many things we have learned about it in transmitting radio waves, but it is the heart of the receiving set, too. It was developed in an interesting manner about as follows.

*a*) *The Edison effect.* When Edison was experimenting with his incandescent lamp, which is really a vacuum tube, he tried some experiments with a bulb of a different type. [See Fig. 18–18.] The filament in the bulb was lighted by

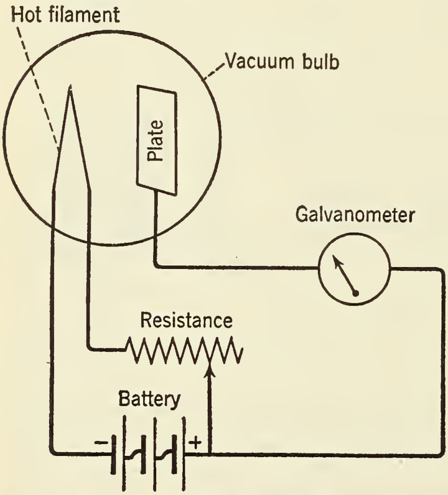



FIG. 18–18. T. A. Edison failed, by a narrow margin, to be a pioneer in radio work. No one could explain how electric current gets from the filament to the plate, and the world had to wait years for radio.

the battery in circuit with it, just as one would expect. When an ammeter or a galvanometer was put in series with the extra plate, which was sealed in the bulb, a current flowed through the ammeter. The experiment was more than a twelve-days' wonder, because no one could explain how the current got across the gap between the hot filament and the metal plate. In time the Edison experiment was almost forgotten.

*b*) *The use of the Edison effect.* About twenty years after Edison performed the experiment just described, Fleming made an interesting discovery. He learned that current would flow from the filament to the plate *only when the plate is attached to the positive plate of the battery " B," and is*

*positively charged.* No current will flow through the ammeter circuit when the negative side of the battery is attached to the plate. Fleming made use of his discovery to make a device used to charge storage batteries. [See Fig. 18–19.]

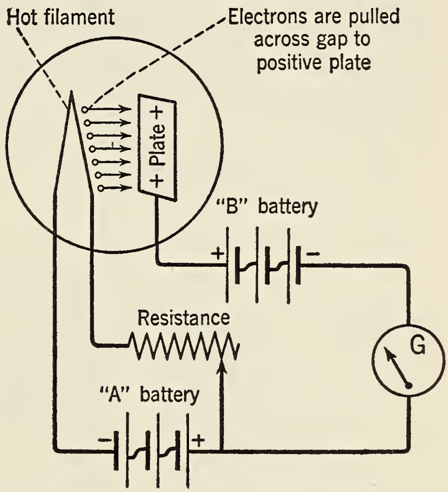



Fig. 18–19. When J. J. Thomson learned about electrons, it became possible to explain the Edison effect. That brought radio reception a step nearer.

What is the explanation? No one knew until J. J. Thomson proposed his electron theory. The hot filament drives out electrons. These electrons are negatively charged particles. When the plate is positively charged, it attracts the electrons from the filament across the vacuum gap to itself, thus closing with an electron stream the gap which had made the flow of current seem impossible. An electric current is believed to be a stream of electrons flowing along a conductor. If the plate is negatively changed, it repels the electrons, and no current flows. Thus the theory accords with the known facts.

*c) The work of De Forest.* An American, Lee De Forest, is the man who made the audion tube the modern miracle that it is today. He introduced an additional electrode, or what is called a *grid,* between the filament and the plate. This grid, which receives the radio waves from the antenna ground circuit, is charged first positively and then negatively.

Hence it acts like a policeman at the entrance to a one-way street, as he permits traffic to flow in one direction, and stops traffic attempting to move in the opposite direction. When there is a *positive charge* on the grid, it helps to pull the electrons away from the hot filament and permits them to flow to the plate and on through the plate circuit. [See the left half of Fig. 18–20.] When there is a *negative charge* on the grid, it turns back the oncoming electrons. [See the right half of Fig. 18–20.]

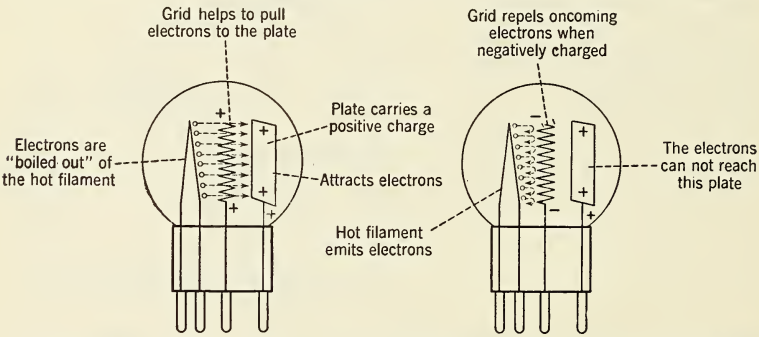



Fig. 18–20. The audion tube developed by De Forest is the heart of radio transmission and reception.

Just as a child can turn on a faucet and thus control hundreds of gallons of water flowing through the water pipes, so it takes only a feeble current on the grid to control even a large current flowing through the plate circuit. Thus the grid changes an alternating current, which flows first in one direction and then in the opposite direction, into a direct current which flows in one direction only. The direct current, however, will be pulsating, or intermittent.

**402. What are the parts of a receiving set?** It is much easier to understand the work of the receiving set if we use a battery set for explanation. We find there are three circuits.

*a*) *The filament circuit.* What is called an A-battery, which may furnish from 2 to 6 volts, is connected in series

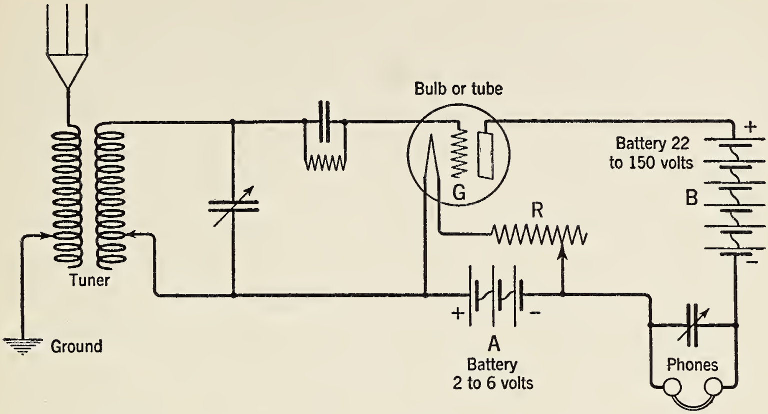



FIG. 18–21. This is a diagram of a simple battery set which illustrates radio reception.

with the filament and a coil of high resistance wire. [See Fig. 18–21.] The resistance of the coil may be varied to permit either more or less current to flow through the filament. As the current flows, the electrons are driven out of the filament. We sometimes say that they are " boiled out " of the filament.

*b*) *The plate circuit.* A B-battery, which may furnish from 20 to 100 or more volts, is so connected in the plate circuit that its positive terminal is joined to the plate of the audion tube. A set of earphones, or a loud speaker, is connected in series in this circuit. One terminal of the loud speaker is connected to the A-battery. A condenser, whose capacity can be varied, is connected across the terminals of the loud speaker.

*c*) *The grid circuit.* The grid of the audion tube is joined in series with the tuner and one terminal of the A-battery. The condensers used in this circuit are for the purpose of balancing the circuits in tuning.

403. **How does the receiving set work?** The radio waves which come from the broadcasting station *induce,* or *set up,* alternating currents in the antenna-ground system. Currents

of the same type are induced upon the grid. These waves are of such a high frequency that our ears cannot detect them. They are called *radio-frequency waves.* By regulating the flow of electrons from the filament to the plate, the grid changes these *radio-frequency alternating currents* into *low-frequency direct currents.* Because their frequency is low enough so that our ears can hear them, they are called *audio-frequency waves.* The audio-frequency waves in the plate circuit are changed in the loud speaker into sound waves which are capable of affecting the ear. In broadcasting, sound waves are changed into electrical waves. Such electrical waves travel through the ether to our receiving sets. Our receiving sets change the electrical waves back into sound waves.

**404. How does a radio set work on the house current?** Many of the small portable radio receiving sets of today operate on a battery or may be plugged into the house wiring circuit directly. Many of the larger sets operate on the house current, which is usually alternating. The voltage, as a rule, varies from 110 to 120. A device which is known as a *rectifier* must be used to change the alternating current into direct current for use in heating the filament, for charging the plate in the plate circuit, and for energizing the magnet of the dynamic loud speaker. The voltage is much reduced for use in heating the filament.

A special tube is used to prevent the hum which is likely to be set up by the *alternating* current. This screen-grid tube is also more efficient in emitting electrons. Several additional audion tubes are used, too, to amplify the radio-frequency waves. By the use of another set of audion tubes, several stages of amplification of the audio-frequency waves are accomplished. Improvements in radio reception, as in other scientific work, are constantly being brought about by the research work of scientists and engineers.

**405. What is television?** The English language is rich in words and is constantly becoming richer. For one reason,

when someone wishes to "coin" a new word, he often borrows from the Latin, the Greek, the French, or from some other language. Sometimes he makes up a mongrel word by borrowing from two different languages to form one word. The word *television* is such a mongrel. The first two syllables come from the Greek word which means *distant, end,* or *far off,* just as it does in the words *telephone* and *telegraph.* The last two syllables are of Latin origin, from the word which means *see.* Now that television is a commercial success, on a rather limited scale, we can listen to a radio program, and watch the actors and artists on the stage as we listen. Possibly the time is not too far in the future when we will see our friends while we hold a conversation with them over the telephone.

In television, too, there must be some method of sending out the pictures of the objects that are seen. They are transmitted by ether waves at the same speed as light and electricity. There must be a receiving apparatus to change such electrical ether waves back into light waves for the benefit of the one who sees.

In the telephone, sound waves are changed into electrical waves by the transmitter, and then changed back into sound waves by the receiver. In television, light waves are changed into electrical waves by a photoelectric cell, and then back into light waves by the receiver of the television set.

*406. **The photoelectric cell is a transmitter.** This "electrical eye," as it is aptly called, is a special vacuum tube. [See Fig. 18–22.] A large portion of the inside surface of the vacuum tube is coated with such very active metals as potassium or cesium (sē'zĭ·ŭm), which are so sensitive to light that they emit electrons when light shines upon them. The more intense the light, the more electrons are emitted. There is a clear window on one side of the cell through which light can enter. The inner surface of the metal is connected with the negative terminal of a battery. Thus it becomes the cathode.

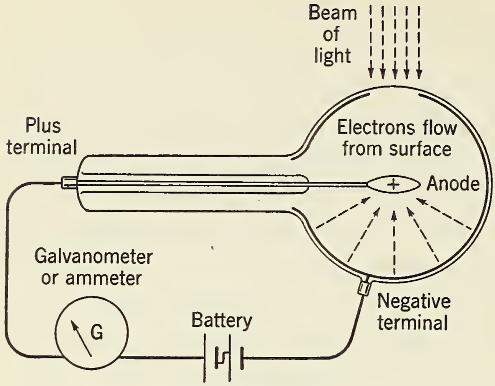



FIG. 18–22. A beam of light may cause electrons to flow from a sensitive surface and thus cause an electric current to flow. The current stops when the light is extinguished.

The positive terminal of the battery is connected to the anode, which is placed at the center of the photoelectric cell. When light shines upon the metals on the inner surface, they emit electrons, and current flows through the cell.

Such an "electrical eye" is used for many purposes. It can be so connected that it will open doors automatically when a beam of light shines upon it, or when a beam of light which had been shining upon it is suddenly cut off. It is used to count the number of automobiles that pass through the Holland Tunnel. If it is connected in a certain way, it may be used as a burglar alarm. It causes a bell to ring when a beam of light shines upon it. It can be used to measure the intensity of light and enable a person to adjust his camera to the proper light conditions. It is used in television for transmitting pictures.

*407. **What is the iconoscope?** When the poet wrote, "The night hath a thousand eyes," he was not exaggerating. But that is a small number when compared to the enormous number of "tiny eyes" which the *iconoscope* uses as a transmitter in television. The inner surface of this vacuum tube is covered with millions of tiny photoelectric cells which give off streams of electrons when light shines upon them. The millions of electrical impulses which are given off from such cells are transmitted from iconoscope tubes and then

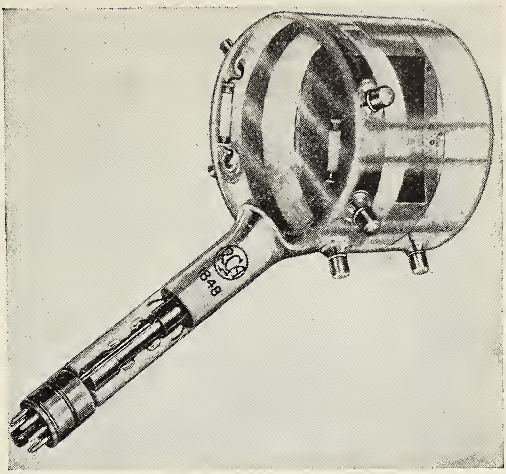


FIG. 18–23. The iconoscope tube has many tiny photoelectric cells. It is the transmitter used in television. (*Courtesy R.C.A. Manufacturing Co., Inc.*)

changed by the receiver into the lights and shadows that form the moving image. [See Fig. 18–23.] The National Broadcasting Company's television station in the Empire State Tower can send out television programs over a radius of fifty miles or more.

*408. **How are pictures received?** The *kinescope*, a tube used as a receiver of television pictures, depends upon the *oscillograph* (ŏs′ĭ·lȯ·grȧf′), in which a stream of cathode rays is projected upon a fluorescent screen. More than 440 lines per inch may be traced upon the screen, which glows when it is bombarded by the cathode rays, which are streams of electrons. They have been emitted from the negative terminal of the oscillograph tube. Such a stream of electrons may be directed up and down, or from side to side, as they pass between plates which are attached to sources of electrical current. The sources of current are controlled by the electrical impulses which are set up in the photoelectric cells by the lights and shadows coming from the object to be "seen." In the kinescope the electron streams cause the fluorescent screen to glow and reproduce a picture. The picture which is seen in the television set is thus reproduced upon the fluorescent screen.

You will recall that the eye continues to see an object for about one-sixteenth of a second after the object has been removed. Such persistence of vision makes possible the blending of motion pictures on a screen. In a similar manner the eye forms a composite picture as it scans the area mapped on the fluorescent screen by the streams of electrons controlled by ether waves transmitted from the photoelectric cell.

## *Questions*

1. We learn by observation, by reading, and by being told. How important is communication in your learning process?
2. Compare methods of communication, at a distance, during colonial times with those in use at the present time.
3. How long did it take in colonial times to send a letter from New York to Philadelphia?
4. What is the purpose of the telegraph sounder?
5. For what purpose is the relay used in a telegraph system?
6. What advantage has the teletype over the telegraph?
7. How does the laying of the submarine cable illustrate the reward that may come from perseverance?
8. Why is it so difficult to tell who invented many of the various machines that have made this a technical age?
9. Does the telephone reproduce all the different sounds equally well? What letters are likely to furnish some trouble over the telephone? Did you ever hear anyone say, "*D* as in David"?
10. Why is the vacuum tube so important in communication?
11. A station broadcasts on a frequency of 600 kilocycles. What is its wave length?
12. A broadcasting station sends out waves that are 250 meters long. What is the frequency?
13. How did a theory help in developing the vacuum tube?
14. What do you understand by radio-frequency waves?
15. What are audio-frequency waves?
16. What simple fact is utilized in the photoelectric cell?
17. What is meant by the persistence of vision, and under what circumstances is it important?

# We See Invisible Friends and Foes Through the Microscope

Sometimes it is the very small, even invisible, thing that becomes important enough to alter man's destiny. A man going on an important trip was driving a large, expensive automobile. On the way, the engine faltered and stopped. The driver tried to start the engine without success. Finally, a mechanic removed a little fly from the carburetor. This insect had been big enough to block completely the entrance of fuel into the engine. The tiniest cinder may cause extreme pain if it is lodged in the eye, and it may prevent vision in that eye until it has been removed. Rarely will a cell continue to live if deprived of its microscopic nucleus.

There are thousands of kinds of organisms, all infinitely smaller than a cinder. Small as they are, and strange as it seems, man's progress has been both helped and harmed by this horde of tiny plants and animals. Most of these tiny organisms are one-celled plants, but some of them are an-

imals. By their aid, civilization was made possible; yet of these microscopic forms, many are the foes of man.

In ancient times people believed that the gods had much to do with causing human ailments. So-called soothsayers and priests sometimes killed animals and examined their organs to foretell the outcome of illness or of battle.

Science has brought us understanding of the causes of many diseases due to the development of germs in the body, and made possible medical treatment of these afflictions.

In this unit we shall learn that there is no use trying to escape from disease-producing germs. Bacteria are everywhere — in the air, water, and soil, and on or in everything we touch. The secret of maintaining health is to fortify one's body and mind by following the rules of health.

## *Think about these!*

1. Do you know the names of any plants or animals so small that you could not see them without a microscope?
2. Can you account for the fact that yeast and mold are found practically everywhere throughout the world?
3. Do you know the difference between a spore and a seed?

## *Words for this chapter*

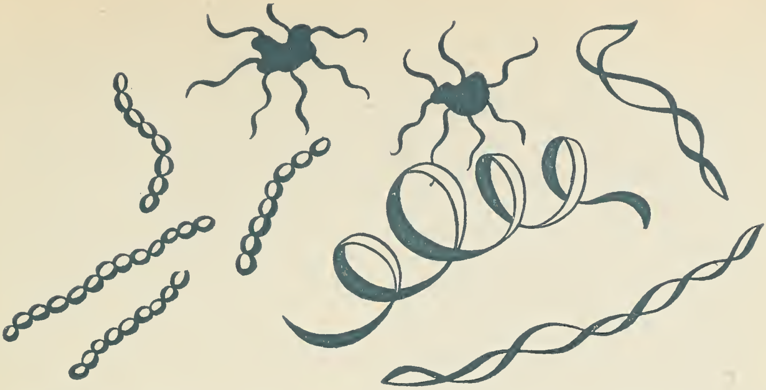
**Microbes.** Microscopic organisms, especially bacteria.

**Fermentation.** The decomposition of a substance either by living organisms called ferments, or by chemical agents called enzymes; alcoholic fermentation is the formation of alcohol and carbon dioxide by the action of yeast upon sugar.

**Volatile** (vŏl′*ȧ*·tĭl). Evaporating rapidly at ordinary temperature.

**Cultures.** Planned growths of organisms on food material or in a favorable environment.

**Zygote** (zī′gōt). A fertilized egg cell.



CHAPTER 19 —————————— UNIT 10

# Why Should We Know about Microorganisms?

**409. Who discovered microorganisms?** About the middle of the seventeenth century – in 1632 – a boy was born in Holland, who, when he grew up, was to be the first person to see such microorganisms as a sperm cell, a bacterium, Protozoa in stagnant water, and whirling blood corpuscles in capillaries. He was only the janitor of the town hall – this van Leeuwenhoek (vän lā′vĕn·ho͝ok′) – yet most of his long life he devoted to grinding tiny lenses and mounting them in metal holders to use in observing microscopic things. He had no college or technical training; throughout life he was self-taught. Yet his discoveries were considered so important that the Royal Society of London made this obscure man a Fellow of their organization, and both the King of Russia (Peter the Great) and the Queen of England came to Delft, his home city, to see his microscopic exhibitions.

Leeuwenhoek did not see those *microbes* which are the cause of the so-called contagious diseases, nor did he suspect how beneficial and also how harmful many of these micro-

scopic organisms are. But his discoveries were amazing enough for his time, and the entire biological world of today recognizes the debt we owe to this Dutchman who finally died at the age of ninety-one, over 200 years ago.

**410. How many kinds of microorganisms are there?** These tiny organisms may be either plant or animal. Most of them are so small that they consist of but one cell, but some are many-celled.

Microorganisms that feed upon dead plant or animal matter are called *saprophytes* (săp′rō·fīts). Those that exist upon the living bodies of other organisms are called *parasites*.

The following kinds of microorganisms are recognized:

| Plants | Animals |
|---|---|
| yeasts, molds, mildews<br>rusts, smuts, Algae<br>bacteria | Protozoa |

Yeasts and some of the bacteria and Protozoa are of greater or less benefit to mankind. Many of these minute organisms, however, are decidedly injurious, and man has to wage a constant warfare against them.

**411. What is yeast?** Put two or three tablespoonfuls of molasses into a flask and then half fill the flask with warm water into which from ¼ to ½ of a yeast cake has been stirred. Let this mixture stand overnight or for a few hours in a warm place. When you next examine the jar, you will see a foamy white scum on the surface. Transfer a drop of this scum to a microscopic slide. Examine the scum first under the low power, then under the high power of the microscope. Each rounded body is a yeast plant. Notice the absence of roots, stems, leaves, and flowers. You will see smaller buds growing from the yeast cells. Are these yeast plants green? If they have no chlorophyll, how can they make food? How can they obtain food? There is a colorless nucleus in each yeast cell which cannot be seen unless the yeast is stained. [See Fig. 19–1.]

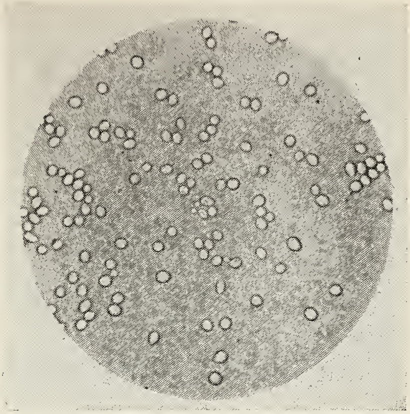


FIG. 19–1. Each of these rounded objects, when seen under the microscope, is an entire yeast plant. Yeast has no stems, leaves, or flowers, nor is it green. How does it get food? (*Courtesy Bausch and Lomb*)

**412. What chemical effect has yeast upon sugar?** If bubbles are actively coming to the surface of the liquid in the flask, introduce into the flask a cork containing a delivery tube and a thistle tube long enough for the stem to penetrate the liquid. Fill two bottles with water, and invert them in a collecting tray. Introduce the delivery tube into the water. Note the bubbles. Place the delivery tube under each bottle in turn, and by downward displacement of water collect two bottles of the gas. (If the gas comes off too slowly, pour water down the thistle tube to drive the

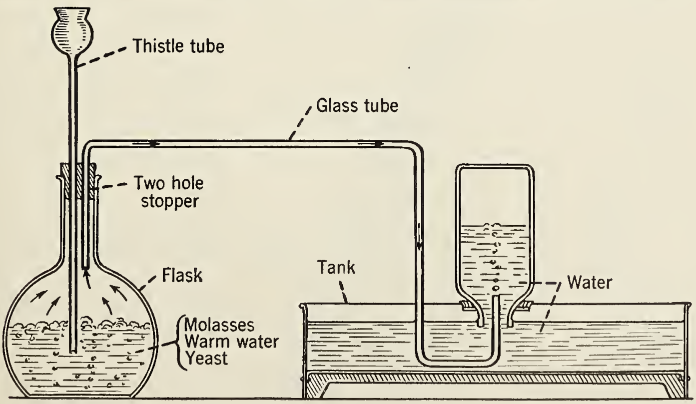



FIG. 19–2. An apparatus for determining the effect of yeast upon sugar.

gas into the delivery tube.) Place a glass cover over the mouth of each bottle and place upright on the table. Introduce a lighted splint into one of the bottles. What is the result? You have studied a gas that extinguishes a flame. What gas, then, do you think is in the bottle? In order to check further on this gas, pour a little clear limewater into the other bottle and shake it. Only one gas that you know will chemically change limewater to a milky color such as you now see. Thus you know that the gas is carbon dioxide. [See Fig. 19–2.]

Yeast has the property of breaking down sugar and water into carbon dioxide and alcohol. The process is called *fermentation.*

Prepare another quantity of fermenting molasses and water in a set-up similar to the preceding experiment. In addition, as shown in Figure 19–3, have a wire gauze (proper support for the flask), a source of heat, spiral condensing tube, or *worm,* of glass, and a beaker. Attach the delivery tube to the worm and place the flask on the gauze over the flame. Heat

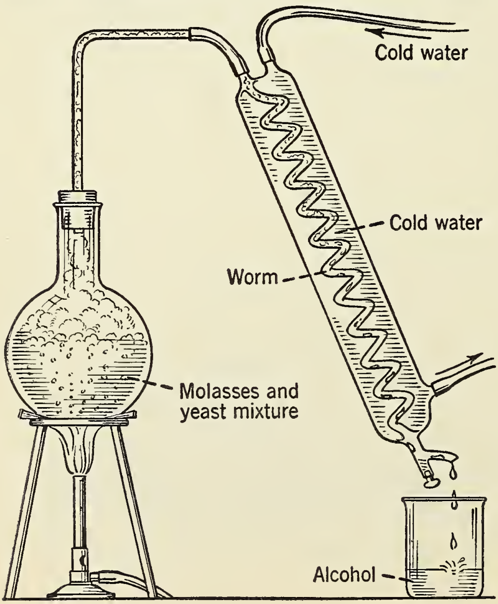



FIG. 19–3. Distillation is easily accomplished by the experiment here indicated. Why is the mixture heated? Why is the exit tube or "worm" spiral shaped? Why is cold water introduced around the "worm"?

gently. If the worm can be kept cold by passing a current of cold water over it or by the use of ice in a cloth wrapped around it, it will work more promptly and successfully. Very soon drops will be seen collecting inside the worm and then dropping into the collecting beaker.

As soon as a small quantity of this liquid has been gathered, smell it to note the odor. What color is it? Put a little into a flat dish and light it. What color is the flame? The liquid is alcohol. This method of separating alcohol from water is based on the fact that alcohol boils at a much lower temperature than does water. Hence it boils and passes off into a vapor before the water can boil and turn to steam. The alcohol vapor is condensed to a liquid when it passes over the cold, inner surface of the worm. In other words, the alcohol vapor is cooled below the condensation point and turns to a liquid. As you have learned, this method of *distillation* is employed in the separation of liquids of different boiling points. Many *volatile* oils used in perfumery and in medicine are obtained by distillation. The apparatus used in the distillation of alcohol from fermenting or other mixtures is usually called a *still*. No still can be legally operated for the manufacture of alcohol without official registration and the payment of a regulated tax to the government.

*413. **What conditions affect the growth of yeast plants?** Obtain five tumblers. Put a label on each and number the glasses from 1 to 5. Half fill glass 1 with warm water and stir into it ⅕ of a yeast cake. Half fill glass 2 with warm water into which has been stirred ⅕ of a yeast cake and to which one tablespoon of molasses or corn syrup has been added. Prepare glass 3 similarly to 2, except that the ⅕ of a yeast cake should first be boiled for 5 minutes in about half a glass of water. Glass 4 is to be prepared as was 2, but ½ teaspoonful of lysol also is to be added. Glass 5 is to be prepared similarly to 2, but ice water is to be used and the glass immediately covered and put into the ice box or into a cold place. Glasses 1 to 4 are to be put into a warm place.

Examine all glasses the next day, and put the cold glass into a warm place for further observation. In which glass or glasses has fermentation taken place? Can you explain the absence of fermentation in some of the glasses? If, in the glass that was cold, fermentation begins as soon as the glass is warmed, what do you conclude? From this experiment, state the conditions favorable to the growth of yeast plants. What conditions are unfavorable?

414. **How is yeast used in breadmaking?** Put two tablespoonfuls of white flour and a teaspoonful of sugar into each of two tall tumblers or jars. Label the glasses 1 and 2. Stir ⅛ of a yeast cake into a little warm water and mix it with the contents of glass 1 to make a moist but stiff dough. Make a similar dough in glass 2, but without any yeast. Place each glass in a soup plate, and let the glasses stand in a warm place overnight. [See Fig. 19–4.]

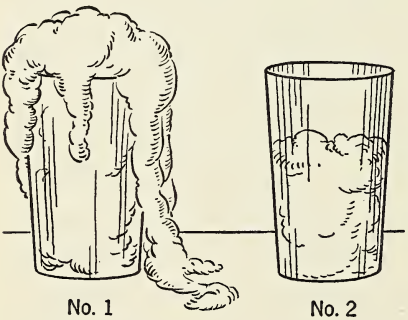



FIG. 19–4. Similar amounts of dough were placed in two tumblers and left in a warm place overnight. A small portion of a yeast cake had been mixed with the dough in No. 1. No yeast had been added to the dough in No. 2. Can you explain the differences in appearance the following morning?

The next day examine the dough in each glass. Account for the difference in height of the two masses of dough. In which do you find bubbles? What imprisons these bubbles? From previous experiments, do you know what gas causes these bubbles? In what respects does this experiment resemble the first experiment in growing yeast plants? Why is dough set in a warm place if one wants it to rise? Examine a slice of bread and compare it with the dough as seen through the glass. Can you explain what causes the holes in the dough

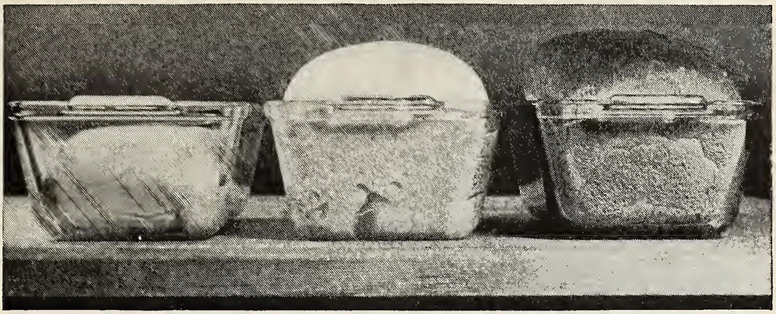


FIG. 19–5. Can you explain what happens in each of these three chapters from the story of bread? (*Courtesy Wheat Flour Institute*)

and in the baked bread? Why is sugar mixed with the flour? Do you ever taste yeast in baked bread? Explain. Do you taste alcohol in baked bread? Why not? In order to have fine-grained bread – that is, bread with small holes – what is done to the dough after it first rises, before it is baked? [See Fig. 19–5.]

**415. How is yeast obtained?** The housewife can get yeast from the grocery store. The store in turn gets it from the wholesalers or the manufacturers. Where do yeast companies procure their yeast? Yeast, as you are probably aware, is a microscopic plant, widely distributed over the earth. If conditions for growth are not favorable, a yeast cell dries up. In this condition, in company with thousands of other yeast cells, it is easily carried off in the atmosphere as invisible particles by gusts of wind. It may drop somewhere into food containing some sugar. If there is enough moisture and warmth, the yeast cells start to multiply and to ferment the sugar. The spores of yeast are also carried around in the air.

There are many species of wild yeast which yeast manufacturers know about. They carefully isolate yeast cells of the kind they want, and start *cultures* of this yeast. A given quantity of these yeast cells is then mixed with a potato mash or starch paste for soft yeast; or with cornmeal or other material for hard yeast cakes. The former will keep fresh only a limited time; the latter will keep almost indefinitely.

**416. Are there vitamins in yeast?** It has been discovered that yeast contains several of the most-recently discovered vitamins coming under the vitamin B group and thus may be of the greatest importance to the health of the human nervous system. Yeast also contains vitamins A and P-P, which aid vision, strengthen the nervous system, and prevent the disease called pellagra and also certain skin troubles.

**417. How can we grow mold?** No one has ever had the experience of camping in the woods when the weather was rainy or damp, without knowing what mold looks like. It seems to grow on almost anything that has become damp.

Let us try to develop a crop of mold. Take a slice of white bread, moisten it slightly, and rub it gently on a place where dust has accumulated. Now obtain a glass-covered dish and put some moist paper in the bottom. Place the bread on the paper, with the dusted surface uppermost; moisten the surface; cover it and put it in a warm place for several days.

In a few days a growth of mold should develop on the bread. Wait until some dark balls appear among the hairy growths, then examine it closely.

**418. What does a mold colony look like?** By the use of a magnifying glass we find it fairly easy to examine mold plants closely enough to answer the following questions.

Do you find any leaves? Break apart some of the bread to see if the mold plant has roots or something resembling roots. Describe the slender stems. Have they any chlorophyll? You know that without chlorophyll, they cannot manufacture their own food. Where do they get it? The answer is that their rootlike parts, unlike true plant roots, can secrete enzymes which digest nutrients like starch. This explains why they can live on starchy foods.

The small, black balls on the tops of certain threads are spore cases. Mold is one of the flowerless plants and reproduces by these spores instead of by seeds. Mold also reproduces by the joining of two stems to make a rounded, dark mass with a heavy protective wall. This is something like a

spore but consists of many cells with a thick covering. It is called a *zygote*. Such a zygote may endure severe conditions and yet continue to live. From it a mold plant will grow when conditions are favorable. Mold will also reproduce from fragments of living mold plants. Its spores are even smaller than yeast cells. When dried they can easily be carried around in the air. Does this give you a clue as to the growth of this mold colony?

Notice the odor of the bread, and examine the parts of the mold plants under the low power of the compound microscope, especially noting the spores.

*419. **What conditions affect the growth of mold?** By experiments using slices of thoroughly dried bread and moist bread placed under the same conditions of temperature and light, it will be easy to note the relation of moisture to the growth of mold. Most persons are aware that foods such as beans, peas, flour, crackers, and the like, may be kept indefinitely if they remain dry.

By further experiments, scientific conclusions can be reached as to whether molds grow better in sunlight or in darkness; in warmth or in cold. Find out whether extreme cold will kill both the spores and the rest of the mold plant. Does boiling kill mold? Does it kill the spores? Is mold affected by alcohol and disinfectants?

Fig. 19–6. These pears have been protected by paper wrappers during shipment. If they came to you, how would you protect them from decay? Is it possible to keep fruit at too low a temperature? (*Courtesy Journal of Living*)

Can you see any reason, other than for advertising or compliance with the sanitary law, why tissue paper is wrapped around oranges and lemons and wax paper around bread? From experimental evidence, can you state why vegetables and fruits should be stored in a cool and dry place? Why should the breadbox in the home be frequently and thoroughly washed with soap and very hot water? [See Fig. 19–6.]

**420. Are molds of any benefit to man?** Molds are introduced into certain kinds of cheese to produce desired flavor and appearance. Molds are also of considerable importance in helping to break down wet leaves, piles of manure, and old logs into chemical substances which enrich the soil. Humus, the rich topsoil of forests, is partly caused by the action of mold. Mold also assists in the production of butyl alcohol.

**421. What are mildews?** *Mildews* are plants smaller than either yeast or molds, which are widely distributed by means of spores. These very light, microscopic spores may develop into colonies of tiny plants if they find favorable conditions of moisture, food, and warmth. Further growth will form white, gray, or bluish patches on leaves and stems of plants, fruits, cloth, seeds, leather, wood, and practically all kinds of food. These patches consist of thousands of individual mildew plants. The mildew plants spoil enormous quantities of fruits by attacking slightly bruised spots and then spreading through the rest of the fruit. The best preventive for living plants is to dust the plants with sulfur, or better, to spray the plants repeatedly and thoroughly with Bordeaux mixture or some other standard fungicide. New tents should always be soaked in an antimildew solution before being used.

To make antimildew mixture, thoroughly dissolve ½ pound of sugar of lead and ½ pound of alum in a pail of warm water. This will take some time, and there will be a sediment. Pour off the clear liquid into a tub or barrel. If the tent is new, wash it before treating it, in order to remove starchy sizing. Soak the cloth or tent in this clear liquid for 24 hours. Hang

it up, but do not wring it out. One antimildew treatment will be effective for several years.

422. What are rusts? It has been found necessary in recent years, throughout many rural communities near pine forests, to destroy both cultivated and wild bushes of currants and gooseberries. Frequently the local inhabitants have not willingly co-operated, until they have been told the complete story of the white-pine-blister rust, which was accidentally brought into the United States from Europe in 1910, and which produces a disease which attacks and kills the white pine. The plant organism causing this damage is called a *rust* because of its color. It somewhat resembles mildew, though much smaller. Curiously enough, it requires a currant or gooseberry plant in which to grow before it changes into the deadly form that attacks the white pine. Cut down these bushes and the rust is prevented from reaching the valuable trees.

There are other rusts which were known long before the white-pine-blister rust. One of the most prominent is the

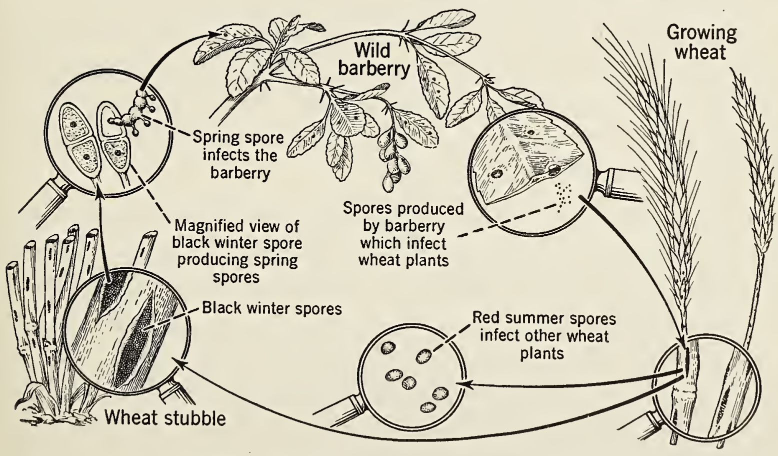



FIG. 19–7. Wheat rust has a strange life history, involving the wild barberry bush as well as the wheat plant. This rust can be eradicated from any region if all the wild barberry bushes (not the cultivated barberry) are cut down.

wheat rust which attacks various kinds of grain. This, too, requires an intermediate *host* before it attacks the wheat. This host is the wild barberry. In many regions wheat has been badly affected as long as the near-by barberry plants were allowed to live. Even the American colonists at the time of the Revolutionary War knew that barberry was a plant unfriendly to wheat, though they did not then know why. Now we know that there are two kinds of wheat rust: red and black. Spores from black rust will not germinate unless they reach barberry bushes. Hence by eradicating barberry plants, this enemy of grains can be controlled. [See Fig. 19–7.]

*423. **What are smuts?** The plants of wheat, oats, barley, and onions sometimes turn black in places and fail to develop seeds. This is usually found to be due to the development of a parasitic plant called a *smut.* There are said to be over 2000 species of smuts, all of which are destructive. The blackened parts of the plant are masses of microscopic spores of smuts which when dry are blown over into healthy plants and thus spread the trouble.

In the case of oats, soaking the seeds in a weak mixture of formaldehyde and water, or heating the grain before planting will kill any spores that might be present. If a corn plant is affected with smut, the best thing is to destroy the plant before it infects other corn plants.

424. **What are Algae?** The *Algae* are members of a great group of plants, mostly simple in structure. Many of them are microscopic, and all possess chlorophyll, so that they generally appear green.

Algae are so widely distributed that they can be found everywhere on the earth, even in the polar regions. They grow abundantly in or on moist soil, on the bark of trees, on the walls of aquaria, in pond water, and in the ocean. When dry, they may be carried around in the air.

425. **What kinds of Algae are there?** In addition to the green chlorophyll, most of these plants possess another pig-

ment, or color by means of which they are usually named. There are four groups of Algae that can be distinguished by their special color. Thus we have the blue-green, the green, the brown, and the red Algae. In addition there is another group of Algae called the *diatoms.*

*426. **What should we know about the blue-green Algae?** It is probable that the blue-green Algae are more abundant all over the earth than is any other plant. They grow in both fresh and salt water. In fact, the Red Sea owes its name to the abundance of a reddish species of this kind of Algae, which seems to color that body of water. The green coating that frequently appears on parts of ponds is usually due to the growth of another species of the blue-green Algae. These plants also develop rapidly on the sides of flower pots in greenhouses and in our houses. [See Fig. 19–8.] They are remarkable plants. They can resist dry conditions indefinitely, having been known to stay alive in dry soil for as long as 70 years. Freezing does not kill them. Nor does hot water, for they are about the only plants that can live in hot springs where the temperature may go as high as 185° F. In fact, the brightly colored borders of these springs are minerals that have been deposited from the hot water and colored by these blue-green Algae. They also are of considerable assistance in helping to break down sewage in streams.

FIG. 19–8. Blue-green Algae are probably more widely distributed over the earth than any other plant. The green coating that often appears on the surface of ponds is made up of millions of these plants. Blue-green Algae also develop on the sides of moist flower pots in greenhouses.

*427. **Why are the green Algae of interest?** This group consists of more than 5000 species, all of which possess chlo-

rophyll. Some of these green Algae are considered to be the simplest plants in the world having chlorophyll. Many species of these Algae reproduce by swimming spores that resemble the sperms of animals.

*428. **What kinds of green Algae are likely to be seen?** On the sides of trees, and sometimes on rocks and fences, especially on the shaded north side, can usually be found patches of green. When examined under the microscope, this green material is seen to consist of living, rounded, green cells. Each of these little cells is a single plant of Protococcus, one kind of green Algae. This tiny organism grows on every part of the earth. [See Fig. 19–9.]

FIG. 19–9. The green patches which one sees frequently on the north side of a tree consist of microscopic green cells of Protococcus, one of the green Algae.

On the surface of stagnant water there usually develop various kinds of pond scums. They are near the surface of the water because, having chlorophyll, they make starch and give off oxygen. The bubbles of this gas collect in the plant and buoy it up. In one of these plants called *Spirogyra* (spī′rō̇-jī′rȧ), the chlorophyll strands are arranged like spiral bands, sometimes as many as sixteen strands in one cell. This beautiful arrangement can be seen only with the microscope. [See Fig. 19–10.]

There are hundreds of other species of green Algae that are microscopic forms and that help to comprise what are called *plankton,* from the Greek word *planktos* which means "wandering." These minute plants, together with tiny animal forms, are the basic food supply for fish and other water animals.

Some of the green Algae produce a fishy flavor in drinking water in reservoirs. Copper sulfate, which quickly affects

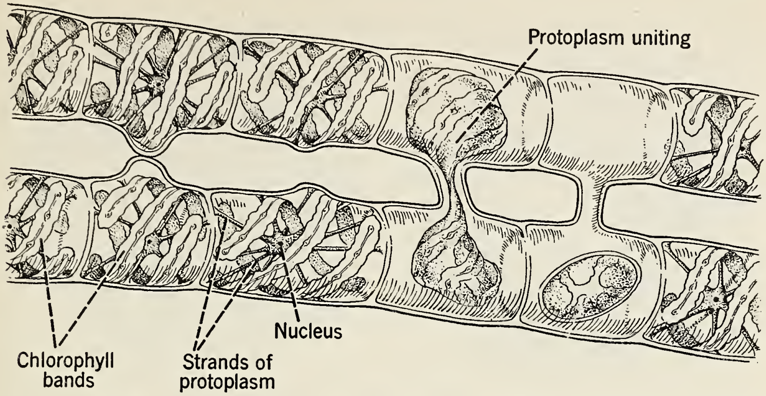



FIG. 19–10. One member of the green Algae is called Spirogyra. A clump of it, when taken out of the water, looks like a mass of green fibers. Under the microscope, each fiber is seen to consist of cells joined end to end. Each cell has walls, chlorophyll bands arranged spirally, and a branched nucleus.

algae, even in quantities as small as one part of copper sulfate to fifty million parts of water, controls this type of Algae.

*429. **What are the brown Algae?** Most of the brown Algae are large, marine plants, some attaining a length of 200 feet, and are usually attached to rocks at the seashore. Few of the brown Algae are microscopic. Potassium compounds and iodine are obtained from *kelp*, a form of brown Algae.

*430. **What are red Algae?** In the red Algae, constituting the so-called seaweeds of the sea, a red pigment masks the green chlorophyll. None of them are microscopic.

431. **What are diatoms?** Diatoms are one-celled Algae which deposit *silica*, a hard substance like sand, in their cell walls. There are over 12,000 species of diatoms and enormous numbers of each species. Under the microscope these tiny organisms appear as minute shells with an infinite number of shapes and kinds, and as some of the most beautiful of microscopic objects on account of their delicate structure. Like other Algae, they are widely distributed over the earth. They occur in moist soil and in both fresh and salt water. [See Fig. 19–11.]

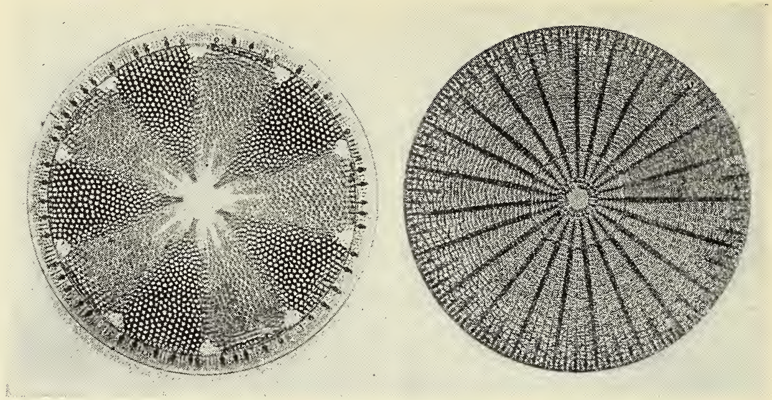


FIG. 19–11. The markings on diatoms make them more beautiful than most other organic structures. (*Courtesy Bausch and Lomb*)

From an economic standpoint there can be no doubt that diatoms are directly or indirectly one of the most important sources of food supply for fishes and other aquatic animals. The deposits of their so-called " shells " are the chief ingredient in powders used by man for polishing.

**432. What are Protozoa and how important are they?** *Protozoa* is the name applied to members of a group of one-celled animals consisting of an enormous number of species, perhaps 10,000, most of which are found in water. Some of them develop hard coverings like little shells. Accumulations of such shells on the bottom of the ocean have built up great layers. In some places such as Dover, England, these accumulations have been pushed up by earth forces until they now form huge, white, chalk cliffs, giving the world new land areas. Deposits of other kinds of Protozoa shells are now found to be valuable to man for use in polishing jewelry and metals.

Many Protozoa are harmless to human beings, but others are injurious to us or to other animals, in whom they cause various diseases. If not injurious, Protozoa may be objectionable as some can cause peculiar flavors and odors in drinking water.

**433. What does a Protozoan animal look like?** It may seem strange to be talking about an *animal,* only to find that it is one cell big or small! Yet such a microscopic form lives by the same fundamental animal functions or activities found in a higher animal. [See Fig. 19–12.]

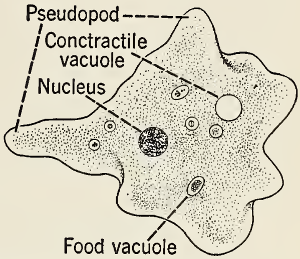



Fig. 19–12. The Amoeba is only one cell in size, but it is one of the best-known animals in existence. It represents the simplest type of animal which has a free, independent life. It moves about by means of *pseudopods,* which are extensions of the main body.

If we examine a living *Amoeba* (ȧ·mē′bȧ) we shall perhaps be able to learn some new things about living forms.

The Amoeba lives on decaying leaves and stems in stagnant water. You may not be able to find an Amoeba in the scrapings of such debris, the first time you try it. It is safer to depend upon a biological supply company which keeps cultures of such animals.

Let us assume that you have secured water in which Amoebae are present. Place a drop or two on a microscope slide, put on a cover glass, and examine the slide under the low power of the microscope. Do not be misled by round, dark circles (air bubbles), or by inactive, irregular masses of nonliving stuff. Sooner or later you will see a creature similar to that shown in Figure 19–12 slowly moving along.

This will be an excellent chance, perhaps the best in your life, to observe protoplasm. Make the most of it. See how this fluid, living stuff, dotted with dark granules, flows out into an extension here and a new one there. You see the nucleus, a larger mass somewhere in the interior, and a clear bubble, the *vacuole.* There will be many food particles of various shapes. Note the absence of a head or special fixed parts. Also note the transparent, outer layer.

The Amoeba is the simplest animal in the world. It has no special organs, yet it recognizes food and retreats from heat and acids. It forms a new animal in the simplest way possible, that of dividing into two parts, each of which grows into a full-sized Amoeba. Can you name any plants that can reproduce from a piece of their structure, not by seeds? What cells in the blood of animals look somewhat like the Amoeba?

**434. What Protozoan can make its own food?** A curious little *Protozoan,* or member of the Protozoa, called the *Euglena,* is frequently found in laboratory cultures. [See Fig. 19–13.] This creature, as you can see under the microscope,

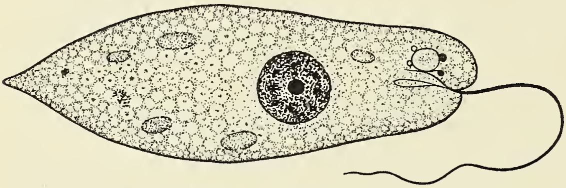


FIG. 19 – 13. The strange little Euglena is an animal but has chlorophyll, like a plant.

is actually greenish like a plant, yet it is an animal and goes darting through the water by means of its long, hairlike whip attached at one end. The green substance in this animal is chlorophyll. From your previous knowledge, what food can such an animal make? This animal probably does not eat solid particles of food like other animals but uses the food its chlorophyll manufactures.

**435. Of what importance to man are parasitic Protozoa?** Perhaps the most unwelcome Protozoan, so far as man is concerned, is the one that causes malaria. Just before 1900 and the beginning of the new century, English and Italian scientists proved that the disease malaria is not caused by bad (*mal*) air (*aria*), but by the bite of a mosquito. This discovery has been checked and rechecked by many experimenters. Today we are sure that the bite of the female Anopheles mosquito, which has previously bitten a malaria patient, is the principal way by which malarial germs, or malarial parasites, as these Protozoa are called, infect the blood of a human

being. It is too much to expect to eradicate this mosquito, because it is distributed over all the tropical regions and in some parts of the temperate regions of the world. But by knowing that it comes out generally only at night, and by using screens and mosquito netting, as well as oiling the surface of breeding pools where that is possible, infections can be greatly reduced.

If a person is infected, the spores introduced into the blood by the bite of the mosquito soon enter red blood cells. They consume the contents of such infected cells and themselves divide into more spores. These spores, escaping into the blood, enter more red blood cells and cause alternate chills and fever. Usually the disease can be controlled by quinine. If a female mosquito bites a patient suffering from malaria, she takes into her stomach, blood with some of the malarial spores in it. In the body of the mosquito these spores form both male cells (sperms) and female cells (eggs). These unite and later divide into countless, sliver-shaped spores, which work their way to the mouth parts of the mosquito. When she next bites, some of these spores are injected into the blood of the new victim, and the cycle is started over again.

*436. **Are there other parasitic Protozoans?** (*a*) There is an Amoeba which, if swallowed in contaminated drinking water by a susceptible individual, may develop in the intestines. Here it multiplies, and these Amoebae attack the inner membranes of the intestines, causing the serious condition known as dysentery. Such Amoebae may also cause internal abscesses in the liver or the brain.

*b*) Another Protozoan, found normally in Africa, is the cause of a strange malady called sleeping sickness. This parasite, called a *Trypanosome* (trĭp′ȧ·nō̇·sōm′), is carried to human beings by the bite of a species of *tsetse* (tsĕt′sḗ) fly. Later the Trypanosome attacks and poisons the nervous system, thus causing fever and general weakness in the victim. Unless the disease is arrested by modern treatment such as

"Bayer 205," the victim will probably die, after a prolonged illness in which he or she is asleep most of the time.

*c*) Texas-fever is a disease of cattle which is due to a Protozoan parasite, *Babesia,* transmitted by the bite of a tick, a creature somewhat like a small spider. In many parts of the world it has killed large numbers of cattle. Although it has caused losses in this country of $60,000,000 in the southern states, it is now fairly well controlled by three measures: (1) pastures known to be infested with ticks are left empty for a few months until the ticks die; (2) ticks on cattle are killed by driving the cattle into vats containing crude petroleum or arsenical mixtures; (3) native cattle are crossed with foreign cattle immune to Texas fever, thus producing descendants which are also immune.

*d*) About the middle of the last century, the great Frenchman, Pasteur, discovered the Protozoan parasite, *Nosema,* which had been killing silkworms in France. This disease called *pebrine* was controlled by destroying all infected eggs and worms and rearing silkworms only from noninfected eggs.

*e*) There are many other parasitic Protozoa, some of which cause tropical diseases such as *kala azar* and *oriental sore,* as well as various diseases of lower animals.

## QUESTIONS

1. Can you tell something about Leeuwenhoek, the discoverer of bacteria and other microorganisms?
2. Can you name several types of microorganisms?
3. What is the difference between a saprophyte and a parasite?
4. Can you describe an experiment demonstrating the action of yeast upon sugar?
5. Do you consider that fermentation has been productive of more good or of more evil in the world?
6. What is distillation, and what principles are involved in this process?

7. What conditions favor, and what conditions retard, the growth of yeast? What conditions kill yeast?

8. Is it better to buy yeast, or can one depend upon wild yeast?

9. What vitamins are obtained from yeast?

10. What are the parts of a typical mold plant?

11. Can you explain the presence of the mold which we frequently find on food and other substances in damp places?

12. What conditions aid, and what conditions prevent, the growth of mold?

13. In what different ways can mold reproduce?

14. What can be done to prevent the growth of mildew?

15. Can you give the life history of some rust, showing how it can be controlled?

16. What are smuts?

17. Of what economic importance are some of the Algae?

18. How are Protozoa helpful to man?

19. How are Protozoa injurious to man?

20. Name a protozoan animal which can manufacture its own food like a green plant.

21. What is the life history of the malarial parasite?

22. How has Texas fever among southern cattle been controlled?

## *SOME THINGS FOR YOU TO DO*

1. Write to the United States Department of Agriculture, Washington, D. C., for bulletins containing information about one or more of the following: (*a*) pine-tree-blister rust or wheat rust; (*b*) mold; (*c*) mildew; (*d*) smuts. Make a report to the class after you have examined the information.

2. Write to a company which manufactures yeast, and ask for any information that company may issue about the preparation of yeast. Prepare a report on the manufacture of commercial yeast.

3. Examine specimens of rust, mildew, and mold under the microscope.

4. Examine under the microscope some of the water and ooze gathered from a stagnant pool, to observe different kinds of living microorganisms. Learn how to culture different Protozoa.

## *Think about these!*

1. What regions on the earth have the fewest bacteria? Why?
2. Do you believe that a tiny cell, so small that it would take 1500 of them to stretch end to end across a pinhead, might be more dangerous to a man than a wild beast?
3. Do you know why the victories of Pasteur had a greater effect on the world than any won by Napoleon?

## *Words for this chapter*

**Aerobic** (ā'ĕr·ō'bĭk). Bacteria that require oxygen in contrast to other bacteria that can live without free oxygen.

**Anaerobic** (ăn·ā'ĕr·ō'bĭk). Bacteria that can live without free oxygen.

**Agar** (ä'gär). A substance extracted from seaweed; it resembles gelatin.

**Pathogenic** (păth'ô·jĕn'ĭk). Capable of causing disease.

**Toxins.** Poisons produced by pathogenic germs.

**Virus** (vī'rŭs). A poisonous and contagious substance apparently able to pass through the finest porcelain filters and still be capable of producing a specific disease in plants or animals.

CHAPTER 20 ——————— UNIT 10

# Are Bacteria Friends or Foes of Man?

**437. What are bacteria?** The important subject of bacteria has been left for the second chapter in this unit.

Since the time of Leeuwenhoek, so many scientists have studied these microscopic plants, that a separate science, that of *bacteriology*, can now be studied in colleges. In fact, bacteria are so closely related to health that a general knowledge of bacteria is essential for every doctor and every biologist. Bacteriology is the basis for all sanitary measures.

Although bacteria have no chlorophyll, scientists have finally agreed to classify them as plants. Since a bacterium is so small — consisting of a tiny particle of protoplasm surrounded by a cell wall, and perhaps with a nucleus — we may well regard it as the simplest plant in the world.

Bacteria occur in three different shapes: ball-shaped, called *coccus* (kŏk′ŭs), plural *cocci* (kŏk′sī); rodlike, called *bacillus* (bȧ·sĭl′ŭs), plural *bacilli* (bȧ·sĭl′ī); and corkscrew-shaped, called *spirillum* (spī·rĭl′ŭm), plural *spirilla* (spī·rĭl′ȧ).

Some bacteria — bacilli and spirilla — are able to move about by means of hairlike extensions called *flagella* (flȧ·jĕl′ȧ). Bacteria also are seen moving back and forth in a sort of vibration. Sometimes there seems to be a rolling or spiral motion.

Bacteria are so exceedingly small that 1500 bacilli, if they could be placed end to end, would hardly reach across the head of a pin. Many of them are barely visible even under the highest power of the average school microscope. So it is not easy to observe either their structure or their activities. We can see bacteria without the help of the microscope only when they have multiplied into thousands or millions of individuals. They usually appear as a slightly colored and more or less slimy mass.

**438. What functions are performed by bacteria?** Some bacteria, like common plants and animals, require a constant supply of oxygen. These are called *aerobic* bacteria. Yet strangely enough, other bacteria cannot live where there is any free oxygen. These are called *anaerobic* bacteria. Still others can live either with or without free oxygen.

Bacteria produce enzymes by means of which they digest substances containing nutrients. Almost any kind of organic matter, such as leaves, wood, leather, glue, starch, meat, or blood, may thus become food for bacteria. This action of bacteria on substances which they use for food breaks down the original substances into various compounds. Eventually, the material is changed into water, carbon dioxide, and mineral compounds which usually pass off into the soil ready to be used by plants for food building. The process of breaking down organic substances by bacteria is called *decay*. It is accompanied by odors very unpleasant to us but apparently well liked by many insects, especially flies and beetles.

Many scientists have watched different kinds of bacteria under the highest power of the microscope until they now know exactly how bacteria reproduce. Reproduction takes place by a simple division of the bacterium into two parts.


FIG. 20–1. Bacteria reproduce by simple division, as do the Protozoa. A wall forms across the cell, and soon the halves separate. Favorable conditions bring about such fission every hour, as seen at the right.

This is called *fission.* [See Fig. 20–1.] Usually the bacilli divide crossways in the middle, and the two cells formed by the division frequently adhere, eventually forming a long chain of cells. Cocci may divide longitudinally forming more or less similar masses. If conditions are favorable, fission of a bacterium may occur each hour. That is, one bacterium at 9 o'clock in the morning would form two bacteria by 10 o'clock. By 11 o'clock there would be four individuals, and eight by 12 o'clock, and so on. If you work it out for 24 hours, you should find that there would be the enormous total of 16,777,216 bacteria produced from a single bacterium. But where there is one bacterium there are usually thousands or even millions more. The grand total possible in a few hours from infection with a mass of bacteria is staggering to imagine.

Under favorable conditions certain bacteria form bodies which are called spores. Sometimes more than one spore is formed by one bacterium. Like the spores of flowerless plants, these little bodies have a thick wall and very little water in their contents. They resist extreme heat and cold and lack of moisture. A temperature higher than boiling (120° C.) is necessary to kill such spores. When a spore is brought into favorable conditions for growth, the wall splits and the spore develops into an active bacterium.

**439. How can we experiment to learn where bacteria may be found?** Prepare nutrient *agar* * and partially fill some Petri dishes. To do so, melt the agar mixture in a flask

* *Standard Methods of Examining a Dairy Product,* published by the American Public Health Association, is one source in which to find directions for preparing nutrient agar.

placed in a steam sterilizer; arrange the sterilized Petri dishes along the edge of a horizontal surface in a room where the air is quiet. Carefully remove the cotton plug from the flask, lift one edge of the cover of one of the Petri dishes, pour enough of the hot agar mixture into the lower part of the dish to make a layer about an eighth of an inch deep, and quickly replace the cover on the dish. Quickly pour some agar into each dish. After the agar has hardened, the dishes are ready for the experiments. Any agar mixture left in the flasks should be sterilized for thirty minutes on each of three successive days in order to make sure that it will keep for subsequent use.

Expose dish 1 to the air of a classroom, by placing the dish on a desk, removing the cover, and leaving it uncovered for five minutes. Then replace the cover and seal the top to the bottom by placing a strip of adhesive tape across the top and the bottom.

Expose dish 2 to soil by dropping, at one side of the dish, a very small quantity of earth in two or three places on the agar. On the other side, touch the agar with some of the scrapings obtained from someone's teeth by means of a toothpick or a sharpened match, previously sterilized by passing it through a flame. Seal the dish as you did before.

In dish 3, on one side place a hair taken from someone's head, and on the other side of the agar make one or two imprints of the tips of fingers after the fingers have been rubbed along a dusty shelf. Seal the dish with tape.

On one side of the agar in dish 4, put a drop or two of water from a cold-water faucet, and on the other side a fragment of food such as meat, bread crumbs, or a piece of banana rind. Seal this dish, also. Dish 5, which is a control, is to be sealed like 1 and is not to be opened at any time. [See Fig. 20–2.]


FIG. 20–2. The control dish of agar is to be kept sealed.

Place all dishes in a warm, dark place. At the end of 48 hours, if you can see well-developed colonies of bacteria on the surface of the agar, bring the dishes out of the dark and examine carefully. A colony or mass of bacteria will be indicated by a rounded spot, usually white or somewhat colored. Mold will be easily recognized by its fuzzy appearance. How many colonies of bacteria or of mold can you count for each experiment? Which has the largest total number of bacteria colonies? Which comes next in quantity of bacteria? List the rest in order of decreasing numbers of bacteria colonies. Examine the control dish for colonies. What do you conclude as to the distribution of bacteria in air, soil, water, food, dust, scrapings of teeth, and hair?

**440. What conditions favor the growth of bacteria?** Provide six Petri dishes of sterilized nutrient agar, labeled on the base from 1 to 6, and one sterilized *but empty* Petri dish labeled 7. From bacteria cultures already on hand, inoculate all these nutrient agar dishes. Inoculation is accomplished by using a small wire cemented into the end of a glass rod. Generally the extremity of the wire is formed into a loop. This wire should be sterilized before using, by heating it to a red heat in a flame. Touch the desired colony of bacteria with the sterile wire loop, lift the cover of the Petri dish, and then transplant some of the bacteria to the agar, using the wire to make some scratches, marks, or designs upon its surface. Replenish the bacteria on the wire frequently. Seal all dishes with a strip of adhesive tape across the top and the bottom of each dish. Dish 1 is to be placed in the refrigerator or


FIG. 20–3. This experiment shows how varying conditions affect the growth of bacteria.

some cold place. Dish 2 and the empty dish 7 are to be placed in a warm room. Dish 3 is to be put in an oven and heated for 20 minutes to a temperature equal to that used when bread is baked or meat is broiled. Dish 4 is to be put in the sunlight. Dish 5 is to be put in the same general place as 4 but covered thickly enough to make it dark. Into dish 6 pour enough tincture of iodine to saturate thoroughly both the markings and the rest of the agar. [See Fig. 20–3.]

At the end of 48 hours, bring out the different Petri dishes and examine the results. From the results found in dishes 1 to 3, what do you conclude as to the relation of different amounts of heat on the development of bacteria? What temperature seems to be most helpful to the growth of bacteria? Keep dish 1 unopened in a warm place for a day or so. If bacteria colonies now develop, what do you conclude as to whether moderate cold will kill bacteria? What effect does it have on the growth of bacteria? Can you make any conclusions as to whether darkness or sunlight is better for the growth of bacteria? Do you find any evidence of new colonies in dish 6? Does this give you a clue as to the possibility of killing bacteria in cuts and wounds in the human body?

**441. How is food treated to keep it from spoiling?** (*a*) *Refrigeration.* Modern methods of refrigeration enable us to keep foods for a considerable time without their being spoiled by the growth of bacteria. Many foods are frozen quickly and sold to the consumer in that condition. Out-of-season fruits and vegetables are thus available in the midst of northern winters.

*b*) *Canning.* We know that extreme heat kills bacteria. This is the secret of canning foods such as fruits and vegetables. They are heated to boiling and while hot are sealed in jars or cans previously sterilized by heat. The dangerous bacteria in milk are killed by the process of pasteurization. In this process the milk is heated to 145°–150° F. for about 30 minutes, and then it is quickly cooled and sealed. [See Fig. 20–4.]

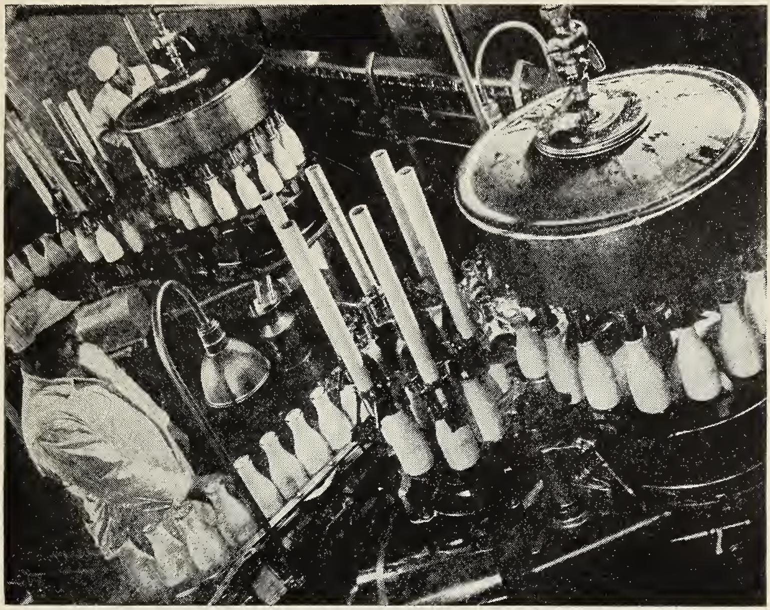


FIG. 20–4. In a modern milk plant, sterilized bottles are filled with pasteurized milk by a machine that fills and caps about twenty bottles at once. (*Courtesy Milk Industry Foundation*)

*c*) *Substances added.* If enough sugar is added to fruits, they can be preserved by the syrup, since bacteria cannot grow in concentrated sugar solutions. Candied quince and citron are examples of this fact.

If meat or fish is hung where it can be saturated with smoke, this develops new flavors and prevents bacteria from growing in such food. Pork, thus treated, is said to be *cured* and becomes ham or bacon.

A harmless substance, salt, is frequently used to preserve certain foods such as pork and fish. By thoroughly soaking the meat or the fish before use, most of the salt can be extracted. Sometimes such chemicals as benzoate of soda have been added to cider, ketchup, and other foods, to prevent the development of bacteria. Such additions to food must be stated on the label according to the Pure Food, Drug, and

Cosmetic Act. The amount of preservative is limited by law.

*d*) *Drying.* Since moisture is essential to the growth of bacteria, food that is thoroughly dried should keep indefinitely. Flour, dry cereals, peas, beans, rice, crackers, dried meat, dried fruits, and many other foods can thus be transported safely for long distances and can be kept without spoiling.

**442. How do bacteria aid mankind?** (*a*) *Bacteria and decay.* There are hundreds of species of bacteria in the world, most of which are either beneficial to man or are harmless. Decay may not seem to be a pleasant subject to think about, but it is very important to the fertility of soil. Think for a moment what would happen if, after January first of next year, there should be no decay. Leaves, stems, bark and roots of plants would not rot away if left on the ground. Nor would

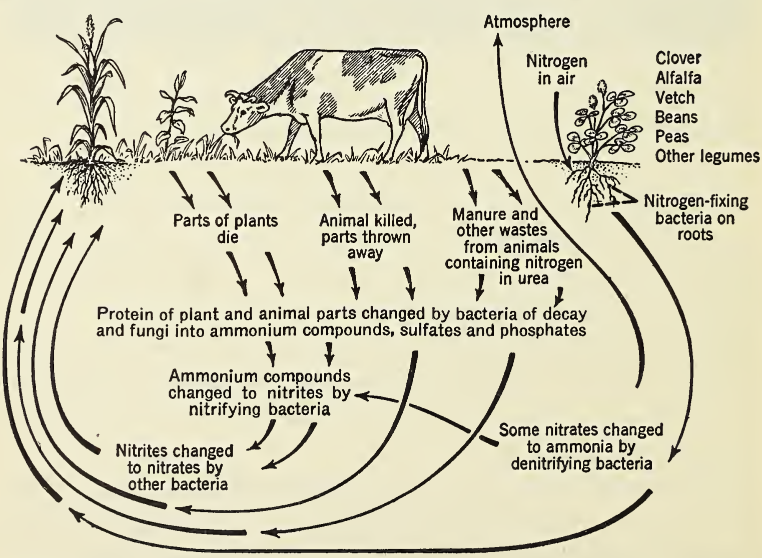



FIG. 20–5. Plants and animal life, therefore agriculture and modern civilization, would be impossible without bacteria. This diagram shows how different kinds of bacteria supply the necessary nitrogen, nitrates, and other compounds for plants, which themselves are eaten by animals.

the bodies of dead animals or their wastes disappear. Soon the soil would begin to lose its remaining mineral substances. Where could it get more? Without decay to return these important mineral compounds to the soil, the compounds would be locked up in the dead structures of plants and the bodies of animals – like money being withdrawn from circulation. If money were taken out of circulation, firms would fail for want of currency, the medium of exchange. If bacteria were locked up, even graver results would take place. Bacteria, the principal agents of decay and of soil fertility, are of immense benefit to mankind. [See Fig. 20–5.]

*b*) *Nitrogen-fixing bacteria.* Manure is an excellent means of making the soil fertile. When manure is placed on the ground bacteria act upon it, changing some of it to ammonia. This ammonia is changed by other bacteria to compounds called *nitrites.* Other bacteria later change the nitrites to nitrates, which can be used by plants.

Bacteria aid in producing soil fertility in another, somewhat similar way. On the roots of peas, beans, clover, and the other legumes, grow nodules, in which are found nitrogen-fixing bacteria. These microorganisms have the ability to absorb nitrogen from the air and soil, and combine it with sodium and potassium compounds, thus forming nitrates, perhaps the most important mineral substance needed by plants. Soil where legumes have been grown, even though very poor before, has its fertility actually increased instead of diminished by such a crop.

*c*) *Bacteria and food.* Lactic-acid bacteria make milk sour by changing the sugar in the milk into lactic acid. The casein, or protein, of the milk is changed to a curd by these bacteria and the lactic acid. This curd is made directly into cheese. Bacteria help to produce the flavor in good butter. Other bacteria can spoil butter by making it rancid.

The flavors of many kinds of cheese are due largely to certain bacteria, or to molds that have been introduced into the milk or the cheese curd by the manufacturer. [See Fig. 20–6.]

FIG. 20–6. Cheese, freshly made, is rather tasteless. Flavors are produced by adding to the cheese certain bacteria or molds which develop during the process of curing the cheese. The cheese-makers store it for long periods in a room where the temperature and humidity are kept constant for even ripening of the cheese. (*Courtesy The Borden Co.*)

Meat from freshly-killed animals is likely to be tough and usually has little flavor. Such meat is therefore kept by meat markets until bacteria have softened the meat and developed the flavor. Certain bacteria called mother of vinegar can change weak alcoholic mixtures over into acetic acid, thus forming vinegar.

*d*) *Bacteria and industry.* Many plant fibers, useful in industry, are loosened from the rest of the stem by the action of bacteria. Flax in particular is kept under water until the stems are softened by bacteria. This process, called retting, allows the fibers of the flax to be easily separated so that they can be spun into thread which is woven into the fabric known as linen.

The stalks of Indian hemp and jute are likewise partially decayed in water by the action of bacteria. In this way, the

FIG. 20–7. Sponges, when brought ashore, are slimy objects. They are placed in huge tanks where the soft parts of these animals of the sea are decayed by bacteria. The skeletons are cleaned, pressed, and sent to market. (*Courtesy The Sponge Institute*)

fibers are loosened and made available for the coarse threads later used in making burlap, cord, rope, matting, and many other articles.

Sponges when brought to the shore are placed in tanks or vats, where the soft parts are rotted by bacteria. The skeletons remaining are then washed, pressed, and baled for market. [See Fig. 20–7.]

In the process of tanning, skins are first soaked in water so that bacteria can assist in the removal of the hair from the hide. This process also aids in softening the skins.

**443. How are bacteria man's foes?** Bacteria of decay increase the fertility of the soil, but unless controlled they also spoil food and many organic products. But more important enemies of man are those bacteria that consume tissues of liv-

ing plants and animals. Bacteria that cause diseases are usually spoken of as germs or microbes, or as *pathogenic* bacteria.

These parasitic bacteria constitute perhaps the greatest natural menace to human health by causing diseases. But man's inventive genius has overcome many of these forms and some of the most brilliant victories chronicled in the story of science are the mastery of such diseases as typhoid fever, anthrax, diphtheria, smallpox, and yellow fever.

**444. Why is Pasteur regarded as the great pioneer in bacteriology?** Such progress in bacteriology dates not from the time of Leeuwenhoek, the discoverer of bacteria, but from Pasteur. With no counsel from experienced bacteriologists, with no books of directions and cautions, he pioneered alone against the ignorance and superstitious beliefs of his time. It was he who first found the specific bacteria in the body of an animal suffering from a certain disease, isolated these bacteria, grew them in a sterile nutrient agar, and then caused the same disease in another otherwise healthy animal by inoculation of that animal with those bacteria. Then he went on to experiment on chickens with old and weak germs of chicken cholera. Such injections, instead of killing the birds, only made them slightly ill. Pasteur thus discovered the principle of making an animal immune to a certain disease by injecting into it weakened germs of the kind that originally caused the disease. This is the scientific theory behind vaccination. Then he experimented upon sheep and studied *anthrax*, an uncontrolled disease fatal to these animals. He developed weakened anthrax germs and declared they would save the sheep. His theories, scorned by the French veterinarians, were put to a great test when he was challenged to a public demonstration. Pasteur accepted. Sixty sheep were used, 10 of which were separated from the rest and were used as the control group. Pasteur then vaccinated 25 sheep with his weakened germs. Then all the sheep, except the 10 set aside, were inoculated with a dose of deadly anthrax germs. In a

week, the whole countryside saw an amazing thing. The 25 vaccinated sheep were as well as the 10 which had not been touched, but the dead bodies of the 25 sheep which had not been vaccinated and which had been killed by the anthrax germ testified to the truth of Pasteur's theory.

Thus Pasteur brought into the world a new and powerful weapon against bacterial diseases, *artificial immunity.*

**445. What is immunity?** It is well known that there is great variation in the degree to which different animals and human beings react to infections and bacteria. For instance, humans, apes, and cattle are susceptible to tuberculosis, while horses, cats, and dogs rarely are afflicted with this disease. Man may be attacked by typhoid fever, but his domestic animals never have it.

Some peoples seem to be naturally resistant to certain diseases. It is said that the Arabs never suffer from typhoid fever and that the Japanese never have scarlet fever. Young children almost never get yellow fever, though as grown individuals later in life they have no such immunity. Many persons are entirely immune from any infection of diphtheria.

From these few cases one can draw the conclusion that there is such a thing as a *natural immunity* to infection by the germs of certain contagious diseases, as a racial, age, or individual characteristic. It is also true that persons who, when in good health, may appear to be completely immune to special infections, may become more or less susceptible to such infections, if their vitality is lowered by insufficient food, overwork, unfavorable climate, injection of drugs, removal of the spleen, or the combination of different germs and antitoxins in the body.

When germs get established in the body, they not only multiply, but they produce poisons called *toxins.* The effects of these toxins may constitute the disease itself. To counteract the effects of the toxins there are produced in the cells of the body certain substances that soon appear in the blood, called *antitoxins.* In most cases the antitoxins developed by the

body kill off the invading germs. The extra amount of antitoxin in the blood of a person who has thus recovered from a contagious disease tends to make that person immune from that particular disease for a shorter or a longer period. Persons who recover from such diseases as measles, yellow fever, typhoid fever, cholera, scarlet fever, and smallpox usually acquire an immunity to these diseases for the rest of their lives. Such immunity is called *acquired immunity.* Unfortunately, not all contagious diseases confer acquired immunity. Such afflictions as pneumonia, influenza, dysentery, and tonsillitis only make the sufferer more susceptible.

In a child, immunity to diphtheria may be determined by a test called the Schick test. Diphtheria toxin is injected into the skin. If, after 24 hours, the region around the injection is red, the child is considered susceptible to diphtheria. If *toxoid* (consisting of especially treated diphtheria toxin) or diphtheria toxin-antitoxin is injected into a child, that child will be rendered immune from diphtheria for a long time. It is claimed that the use of toxoid brings a lifelong immunity. In such a case the normal antitoxin of the body has been reinforced by the addition of extra antitoxin from without. This

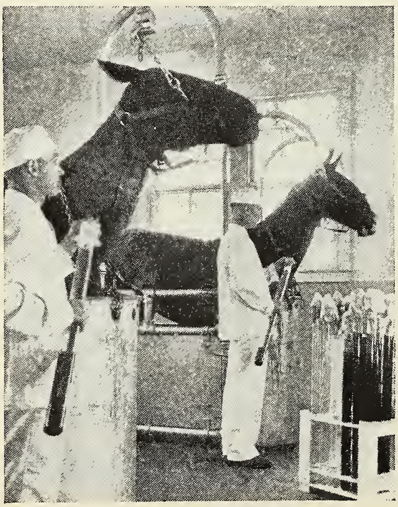


FIG. 20–8. In modern times the horse may seem to be superseded by the automobile, but for furnishing blood serums, the horse is unexcelled. Here, two horses are having blood containing antitoxin taken painlessly from their necks. The serum will be separated from the blood. (*Courtesy Parke, Davis Co.*)

was the principle involved in the vaccination of the sheep by Pasteur. However, it was not until 1892 that a German bacteriologist, Von Behring, found, in studying diphtheria, that diphtheria antitoxin for human beings can be manufactured in the blood of an animal like the horse, and that from the blood of this animal, the serum containing such antitoxin can be used to reinforce the natural antitoxin of the body. [See Fig. 20–8.]

Many new serums which contain antitoxins for many different diseases other than for diphtheria have been developed and are in use. Even a special antitoxin for poison snake bites, called *antivenin,* has been made available. Immunity gained by injections or other artificial means is said to be *artificial immunity.*

**446. How is the body safeguarded against germs?** Germs cannot develop in the body unless they enter with food, with inhaled air, by contact with the mucous membrane of the eyes, lips, or other parts of the body, or through breaks in the outer protective layer of the body—the skin. The hairs in the nostrils catch many germs, and the moist mucous membranes of the nose, throat and the mouth catch still more. Cilia, waving vigorously in the air passages of the windpipe and the lungs, carry out bacteria that have been breathed in. The hydrochloric acid of the gastric juice in the stomach and the strongly alkaline bile in the intestines kill many germs that are swallowed with the food.

Finally, if living germs are able to get by these barriers, or if through cuts or other means they reach any part of the interior of the body, they are there attacked by white blood cells. In the blood antitoxin is soon formed in increasing amounts. In addition, substances called *antibodies* begin to help in the conflict. These are *opsonins* (ŏp′sō·nĭnz) which increase the activity of the white blood cells, *lysins* (lī′sĭnz) which tend to dissolve the germs, and *precipitins* (prē̇·sĭp′-ĭ·tĭnz) which separate out certain foreign substances in the blood.

Ordinarily, foreign bacteria have a very difficult time of it in the human body. In fact, they rarely develop in healthy human tissue. It is probably true that the germs of several diseases like tuberculosis, pneumonia, and diphtheria could be found in the mouth and throat of the average healthy individual. Such germs usually do not develop into an infection because the conditions have not been favorable for their development.

**447. How can natural immunity be increased?** Good health is the greatest blessing in the world. Its value is beyond price. But many people only learn this after they have broken down their health and suffered many troubles through lowered immunity. It is much easier to maintain good health than it is to try to regain it.

First, the general rules of good living should be followed. These are (*a*) the eating of sufficient, but not too much, natural foods, well balanced for nutrients and vitamins, (*b*) pleasurable physical activity, (*c*) enough sleep and rest, (*d*) clean air, (*e*) exposure to sunlight, (*f*) personal cleanliness. One should also protect the body against exposure and fatigue. Just as important in developing resistance to disease is the condition of the mind. "A merry heart doeth good like a medicine" says the Bible. It is quite amazing to find how much the physical health of an individual is raised by good mental health. Fear is not only depressing; it lowers one's vitality. A mind troubled by worry, discontent, envy, or anger alters the secretions of the body, prevents normal digestion, and if continued, brings on ill-health through lowering the natural defenses against bacterial infection.

**448. How can the number of germs be reduced?** Since the experiments showed many bacteria present in dust, it should be evident that if we can reduce the amount of dust we shall correspondingly lower the number of bacteria, especially the dangerous germs.

Whether or not the dust is entirely removed from floors, rugs, carpets, hangings, and furniture, or merely partially re-

moved, when a room is being cleaned, is a matter of method. In some backward places there may still be used that relic of barbarism, the feather duster. It never gathered and took away any dust and it warranted the name of "furniture tickler." Now modern science demands that dust be really removed. Turpentine and wax will change cheesecloth into a "dustless duster," or a cloth slightly oiled may be used. Rugs are more hygienic than are large and heavy carpets. The former can be cleaned fairly easily, whereas the carpet is rarely thoroughly cleaned oftener than once a year, if as frequently.

One of the most valuable aids to cleanliness that modern science has given the home is the vacuum cleaner. The carpet sweeper is also more efficient than the broom. If the broom is used, wet pieces of paper or moist tea leaves scattered over the carpet before the sweeping, help to catch the dust. For the same reason moist or oily sawdust is scattered over wooden floors before the sweeping is begun. [See Fig. 20–9.]

FIG. 20–9. The vacuum cleaner answers the demand for a fully efficient method of cleaning. Experimental evidence has shown that sweeping with a dry broom may produce 297 times as many bacterial infections as are produced with a vacuum cleaner. (*Courtesy General Electric Co.*)

One authority reports statistics * from experiments in cleaning four rugs of the same size by different methods, each in a separate room. Nutrient-agar Petri dishes were exposed for five minutes in each room, before cleaning and during the cleaning. The results showed that there were about 4 times as many bacteria colonies produced by the vacuum-cleaner method as were found in the quiet, unswept room. The use of a carpet sweeper produced about 19 times as many bacteria colonies. The broom with pieces of wet newspaper produced about 72 times as many colonies. The use of the dry broom alone on a rug brought approximately 297 times as many colonies, or an actual total of *1190 in one Petri dish.* The point of this experiment is not that we should never clean rugs and other furnishings, but that there are good ways of cleaning and there are other ways that are bad and even dangerous.

When there is forced ventilation in a building, the incoming fresh air can be passed over moistened screens and the air thus be filtered from dust. A new invention by the Westinghouse Electric Company is the Sterilamp, a special type of bulb whose radiations kill bacteria. This amazing instrument, placed in the air ducts of a forced-ventilation or air-conditioning system, completely sterilizes the incoming air. The Sterilamp has also been used successfully in the operating rooms of hospitals to kill germs in the air and elsewhere. One progressive hotel in New York uses another instrument which gives off ultraviolet light and thus kills bacteria; the rooms are sterilized after use and sealed until again occupied.

The use of disinfectants in the cleaning water is a good precaution if it does not leave an objectionable odor in the rooms. A disinfectant is stronger than an antiseptic and is used to kill germs outside the body. A disinfectant should rarely be used on the human body unless greatly diluted. Carbolic acid, lysol, chloride of lime, and bichloride of mercury are disinfectants. Sunlight is one of the best of disin-

* *Biology and Human Welfare,* by James E. Peabody and Arthur E. Hunt.

fectants. Many communities add chlorine to the drinking water in their reservoirs. Or about 15 pounds of chloride of lime to 1,000,000 gallons of water may be used.

**449. How should wounds be treated?** With our knowledge of bacteria and their possible dangers, sensible persons today are quick to use an antiseptic on cuts and other breaks of the skin. There are several antiseptics which kill bacteria without injuring human tissues. In spite of strenuous advertising by magazines and by radio, experiments indicate that tincture of iodine is still the most effective antiseptic. The popular weak solution mercurochrome is less effective. [See Fig. 20–10.]

If the cut or wound has soil or dust in it, it must be *thoroughly cleansed.* Clean soap and warm boiled water are excellent cleansing agents which may be used before the iodine is applied. If a cut be allowed to bleed for a while, bacteria in the wound will thus be carried off. Then most cuts will require a bandage.

FIG. 20–10. Boy Scouts have a splinter situation under control. (*Courtesy Boy Scouts of America*)

A cut should be bandaged so that directly over the wound there is an antiseptic covering through which air can penetrate but which prevents the entrance of dust. Do not put adhesive tape directly over a wound. Never put iodine on the body and cover it up while moist. It will produce blisters. Iodine in a wound may be washed out with ethyl alcohol to avoid burning the cells. Boric acid in a saturated solution is an excellent, mild antiseptic to use for washing the eyes.

**450. What is a contagious disease?** An illness caused by the development of pathogenic bacteria in the body is usually spoken of as a contagious disease or an infectious disease. The body of the sick person is a place where these germs are alive and possibly spreading. So, the doctor, in accord with the rules of the board of health, quarantines the sick room. That means that people other than the nurse and the doctor are to stay away until the danger of catching the germs is over. This period varies with different diseases. Many persons are afraid of "catching the *disease*." A disease is a sick or weakened condition of body and mind. Such a diseased condition which belongs solely to the ill person can hardly be "caught." But the bacteria can. The germs may be distributed through careless habits of those nursing the patient or through the ignorance of those who might come in contact with the victim.

For instance, one should *never* use a common towel or drinking cup because of the strong probability that someone has left there dangerous germs from hands, face, lips, or eyes. Likewise a person suffering from a cold, influenza, or the grippe, should invariably, when sneezing, cover the nose with a handkerchief. The mucus in the nose and throat contains the offending and dangerous *virus,* or toxin, and a sneeze may spray fine mucus particles through the air for some distance from the careless sneezer.

Quarantine rules should never be broken. They are made for the good of the whole community.

**451. How do scientists classify a disease as caused by germs?** Bacteriologists have agreed not to list a disease among those caused by germs until the following tests have been completed and carefully checked.

*a*) One type of germ must invariably be present in the body of the victim of any particular disease.

*b*) This germ must not be found associated with any other disease.

*c*) This germ must be isolated and grown, free from all other germs, on sterile nutrient agar.

*d*) Injection of some of these pure germs into the body of a healthy animal must always bring about a case of the original disease in this animal.

**452. What are virus diseases?** There are several other contagious diseases of man, for which no germs have yet been identified as the cause. Secretions – especially mucus – of a victim of one of these diseases may infect others. The

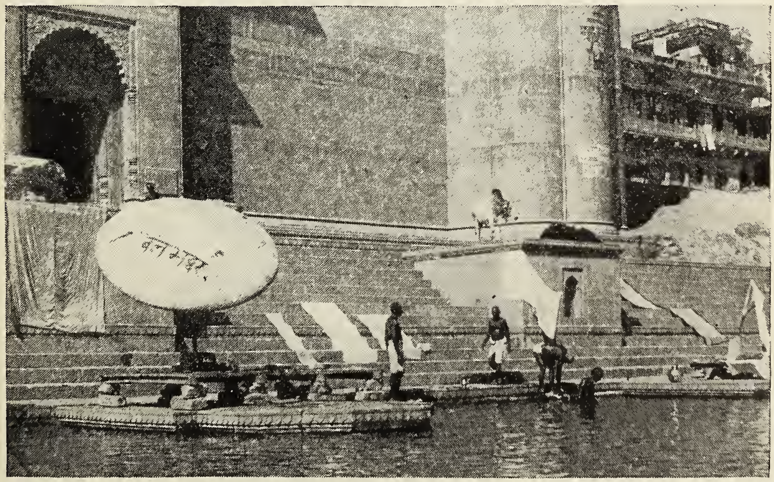


FIG. 20–11. Millions of Hindus bathe in the supposedly holy water of the River Ganges. The banks are lined with temples and flights of steps, like those at Benares shown here. Biologists believe that great quantities of bacteriophage in the water destroy harmful bacteria from diseased bathers. (*Fritz Henle from Monkmeyer*)

poisonous or contagious material consists of particles so fine that they can pass through a porcelain filter which would filter out true bacteria. Thus the name *filterable virus* has been given to the causal agent in any one of these diseases though it has not been isolated. The following are considered to be *virus* diseases: cowpox, smallpox, rabies, scarlet fever, yellow fever, measles, influenza, infantile paralysis, and parrot fever.

There are several virus diseases of plants, chief among which are the so-called *mosaic* diseases of the tobacco and the tomato.

**453. What is bacteriophage?** If you hear some one saying that there are good bacteria that eat up the bad ones, they may be partly right. There seems to be considerable evidence for believing that there sometimes occurs a substance called — for want of a better name — *bacteriophage* (băk·tẽr′-ĭ·ō·fāj). (*Phage* comes from the Greek word *phagein,* meaning *to eat.*) An infinitesimal quantity of this substance, perhaps as little as one part to a million parts of water, appears to be sufficient to digest and thus kill all dangerous pathogenic germs in the liquid. Some germs may secrete their own bacteriophage. [See Fig. 20–11.]

## QUESTIONS

1. What are the different kinds of bacteria?
2. How are bacteria able to use organic material for food?
3. How rapidly do bacteria multiply under favorable conditions for growth?
4. How can experiments prove (*a*) the distribution of bacteria; (*b*) the conditions favorable to the growth of bacteria; (*c*) the conditions that hinder the growth of bacteria; (*d*) the means by which bacteria may be killed?
5. What is nutrient agar and how is it prepared?
6. How does decay aid mankind?
7. Explorers have found the bodies of certain prehistoric ani-

mals in the ice of Siberia; and their flesh was still so fresh that it was eaten by dogs of the expedition. Why did these prehistoric animals not decay?

8. What are nitrogen-fixing bacteria, and how do they aid us?
9. How are bacteria of aid to us in connection with foods?
10. How are foods treated to avoid their being spoiled by the action of bacteria?
11. How are bacteria of importance in industry?
12. Why are certain bacteria considered to be among the chief enemies of man?
13. Why is Pasteur regarded as a great pioneer in the study of bacteria and disease?
14. What is natural immunity? How can it be increased?
15. What is acquired immunity?
16. What is artificial immunity?
17. What is the Schick test?
18. What did Von Behring discover?
19. What is a serum? How are serums obtained?
20. What are the natural safeguards of the body against invading bacteria?
21. What habits of health help to increase individual resistance to disease?
22. What methods of cleaning help to reduce the number of bacteria in homes and other buildings?
23. What inventions aid in reducing the number of bacteria?
24. How are foods treated to prevent decay by bacteria?
25. How should wounds be treated?

## *Some things for you to do*

1. From plasticine, plaster of Paris, or clay, make large models of the different types of bacteria.
2. Try experiments with sterile nutrient-agar dishes, using the general method suggested in the chapter, to see how many bacteria colonies develop after exposures of the same length of time in selected places. Use a regular, black disk designed for counting bacteria colonies.

3. Read about Leeuwenhoek, Pasteur, and other scientists concerned with bacteria. Then write a story giving their contributions to bacteriology.

4. Visit a plant where milk is pasteurized and write a report of your visit.

5. Drop a piece of meat into a bottle, cork the bottle, and put in a warm place. Twice during the next week note all changes involved in the process of decay including odor and appearance.

6. From personal investigation of actual conditions, and interviews with the commissioner of health of your community, write a report on "How Pure Water Is Furnished to My Community."

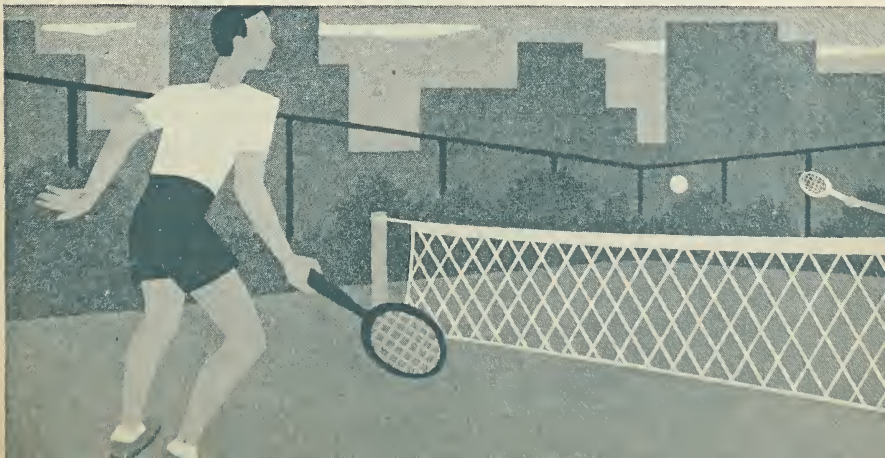
7. Visit a hospital and pay particular attention to the ways in which pathogenic bacteria are avoided and controlled.

# We Are Improving Public Health

DURING man's progress from prehistoric savagery up to his present civilized state, he learned that at times he is helpless because of injury or illness. When he was inactive, others had to do the work he was accustomed to do.

Not all people, however, have cared for their helpless. The Spartans in Greece and some of the Indians in America ruthlessly killed off the ill and aged. However, today those who are weak are usually helped by those who are strong. But that assistance is not always scientific. Even today, in primitive tribes, an ill person is visited by a "medicine" man, who, by making unearthly noises and by lacerating the victim, pretends to drive out of him the devil of sickness.

Pasteur ushered in a new era when he demonstrated that scientific truth is superior to superstitions and beliefs. From his day to ours, there has been a growing acceptance of the positive value of a knowledge of rules of health based upon a science which can be checked and verified.



The microscope has been substituted for so-called "magic," the X-ray apparatus and the fluoroscope for lacerations of the body, and immunity by serums and antitoxins for worthless nostrums. Medicine has become even more useful as a preventive of disease than as its cure. States of mind are extremely important.

The health official of today knows scientific facts of which the wisest of the physicians of earlier years were unaware. But if he is sincere, he also realizes how much there is yet to know and to learn.

The advance of civilization has been marked by co-operative measures designed to maintain standards of health in communities and to bring assistance to the needy. Public health is a dramatic story of the usefulness of man for mankind.

## *Think about these!*

1. Is there a member of the cabinet of the President of the United States, or other official, who is concerned with public health?
2. How did the draining of marshes and the destruction of mosquitoes make possible the digging of the Panama Canal?
3. What disease was formerly called the "Great White Plague"?
4. Why is it very important to ensure safe milk and pure water in any community?

## *Words for this chapter*

**Rural.** In or of the country.
**Diagnosis.** The recognition of a disease by certain symptoms.
**Potable.** Pure enough to drink.


CHAPTER 21 ——— UNIT 11

# Why Is Public Health Important to Civilization?

**454. How did communities originate?** At some time long ago, prehistoric men must have joined with other prehistoric men to form groups for sharing work and for protection. Small groups grew into clans and tribes.

Today great numbers of persons live, work, and play more or less together in communities large enough to be called cities or small enough to be villages or hamlets. Gradually, certain rules for governing such local societies have come into being. In civilized countries all communities practice group rules even at the sacrifice of some freedom of action on the part of the individuals making up that community.

**455. What do we mean by community health rules?** Among the rules or laws of a community, those relating to the health of the community are perhaps the most important. Many rules of health may be followed by individuals. But there must be new and broader rules for the collective good. Standards must be set up for the maintenance of minimum good quality in foods and commodities, and for cleanliness

in the handling and marketing of these and other goods. Ways must be formed to dispose of garbage and wastes from the crowded homes. Wandering tribes could throw refuse almost anywhere. Men cannot do so in the community, where such actions would not be tolerated by close neighbors. The streets and avenues must be cleaned at all seasons. Traffic rules must be followed for the safety of human life. Persons who are ill with contagious diseases must not be allowed to go about among others and possibly transmit dangerous germs to them. Even pets must come under certain regulations. These are only some of the important matters that affect the health of the community.

**456. What health officers are necessary in a community?** In a small community a responsible person like a doctor, a teacher, or a minister is frequently looked to for advice on matters of public health. A village usually elects one of its doctors as the health officer of the community.

In cities there is usually a board of health. This board consists mostly of doctors, with a larger or smaller staff of research workers to make investigations, laboratory technicians to conduct experiments and tests, and inspectors to learn conditions and to represent the board of health in various parts of the community. The chairman of the board of health is the health commissioner for the community. He is responsible for setting up procedures aimed to safeguard the health of the community and for supervising the faithful discharge of the duties of all his subordinates.

The health officer or the board of health is responsible for keeping the *vital statistics* of the community. These statistics are a record of births and deaths, also the causes of death as given by the doctors attending the cases.

To ensure the proper division of labor instead of imposing too much responsibility on one man or on a small group of men, in large cities there may be several departments or bureaus to cover the work for which the health officer or health board in a smaller community is responsible. Thus in

New York City there are the departments of Correction, Health, Hospitals, Parks, Sanitation, Water Supply, and Welfare, all concerned directly or indirectly with the health of the seven million persons living in that city.

**457. What state and federal health agencies are there?** In the state there is one official, or more, in general charge of health matters affecting the people of the state. There are also inspectors and assistants.

The United States government, by means of laws passed by Congress, enforced by federal officers, and aided by the activities of the surgeon general, continually protects all the people of this land. Many government bureaus and departments publish pamphlets and books relating to the health of plants, of lower animals, and of human beings. This country also participates in international conferences for such purposes as the control of the traffic in narcotics, the setting up of standards of health for immigrants, and the prevention of the importation of undesirable insects or of diseased plants and animals.

**458. Why are vital statistics important in public health?** Every community must, as you know, keep an accurate record of births and deaths. If, in addition, these records show the cause of death, the age, the sex, the race, and other pertinent facts about a member of the community who has died, the data may reveal unusual conditions in parts of the community. For example the facts may show special fatalities from traffic accidents; the possible widespread character of certain diseases; the increase or decline of tuberculosis, typhoid, diphtheria, and other contagious diseases among different groups of the population, such as men, women, and children, and the various races. This and other information can lead to the proper remedial measures. Without vital statistics we should be unable properly to appraise the value of many measures directed toward public health.

**459. Why is disease prevention essential in public health?** Trouble of any kind is more easily prevented than

cured, especially when the trouble is a disease. As more and more persons gather together in one community, the responsibility of the health officials for the prevention of the spread of contagious diseases from person to person increases. Field inspections, methods of strengthening immunity, quarantine, sanitaria, and other means of isolating individuals who might be dangerous to others, also experimental research, are all procedures associated with disease prevention.

**460. How has the plague been controlled in the United States?** As an example of disease prevention, let us take the disease of cholera. An inland community in the United States does not have the initial danger to which a great seaport is subject. Yet such a malady, unless controlled in its earliest stages, could sweep over a whole country, as did the plague, or Black Death, in its various visitations. From 1334 to 1351, millions of persons died from this disease which raged throughout Europe and a large part of southern Asia. The latest outbreak was in 1894, when a wave of plague traveled entirely around the world. Since 1914 the work of public-health authorities has brought it under control in the Americas; and it has declined elsewhere also.

The method of control is the result of much research and painstaking precaution. Plague is a disease resulting from infection by certain bacilli which may be transmitted to a new victim by rats, fleas, lice, and flies. Rats and their parasite fleas, however, appear to be the chief agents which spread the plague bacteria. So health authorities at all great ports of this country have declared war on rats. Many buildings around docks have been made ratproof. When ships dock, metal shields are installed on the hawsers to keep any rats that might be on board from landing. Passengers from all vessels are inspected by port doctors to make sure that no dangerous germs are brought into the country. Better sanitary conditions the world over have been invaluable in reducing the spread of the plague, as well as other infectious diseases.

461. What is the dramatic story of yellow jack? Planes that land in this country from tropical regions to the south are inspected both by immigration authorities and by medical specialists. Not only are passengers checked for health, but the planes themselves are inspected, to see if an Aëdes stowaway can be found anywhere. The inspectors know that this name is never on the passenger list since it is the scientific name of a tropical mosquito. But they also know that this dangerous insect is the principal means of distributing the deadly virus of yellow fever. So no chances are taken. In 1938 an examination of 398 planes coming into Miami, Florida, revealed a total of 651 insects, including 40 dead mosquitoes and 5 live mosquitoes. [See Fig. 21–1.]

In 1647, yellow fever or yellow jack, as it is called, was first identified in the West Indies. Since that time, it has flourished to a greater or less degree along the western coast of Africa, on both coasts of South America, and in the West

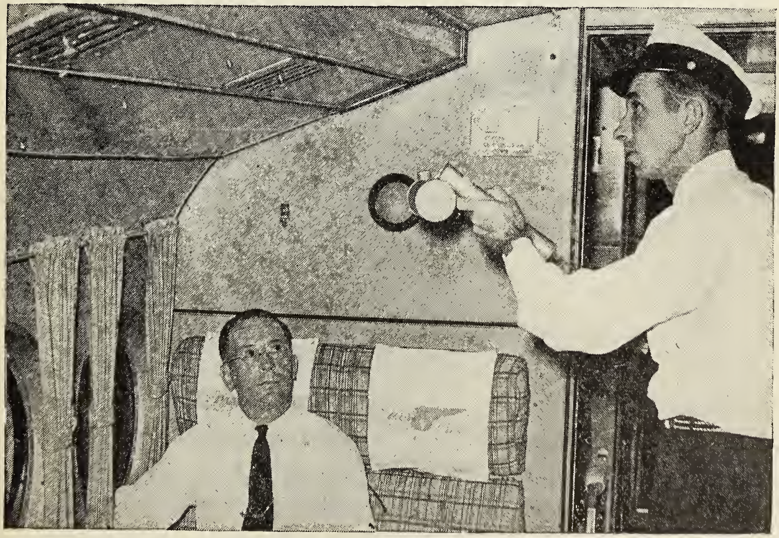


Fig. 21–1. Constant vigilance keeps the Aëdes mosquito from being brought accidentally by plane into the United States, there to start an epidemic of yellow fever. (*U. S. Public Health Service*)

Indies and Central America. It is now generally under control wherever modern methods are employed. Safety from yellow fever today is assured because of the brilliant achievement of four surgeons in the United States Army.

In 1900, President McKinley sent Doctors Carroll, Lazear, and Agramonte to Cuba under the leadership of Major Reed, as a yellow-fever commission to ascertain if possible the way by which yellow fever is transmitted. [See Fig. 21–2.] Dr.

FIG. 21–2. Dr. Walter Reed, a major in the United States Army, was chosen by President McKinley in 1899 to head a commission for the study of yellow fever. The work of this commission in Cuba proved that the Aëdes mosquito carries the microorganism which causes yellow fever. (*American Museum of Natural History*)

Carlos Finlay thought that mosquitoes were at fault. The commission could not accept theory. They required proof. Two of the doctors, Lazear and Carroll, allowed Aëdes mosquitoes to bite them. Both became ill with yellow fever, and Dr. Lazear died. In a hospital in Baltimore, Maryland is a tablet in memory of his heroism with the following sentence: "With more than the courage and devotion of a soldier he risked and lost his life to show how a fearful pestilence is communicated and how its ravages may be prevented."

However, more experimentation was necessary to establish proof that these Aëdes mosquitoes were the actual means of transmitting yellow fever. John Kissinger, an army private, and John Moran, a civilian, offered their services and their lives, if need be, for any experimentation, and without

any special reward. This is one of the rare instances on record where a private was saluted by his superior officer. Major Reed, deeply moved at the sacrifice, said: "In my opinion this exhibition of moral courage has never been surpassed in the Army of the United States."

Kissinger and Moran went into a special building divided by screening. Here, on one side of the screen, they were bitten by Aëdes mosquitoes which had previously bitten persons ill with yellow fever. On the opposite side of the screen were other men but no mosquitoes. Both Kissinger and Moran contracted the disease. Moran recovered but Kissinger was permanently affected. Further experimentation with three other subjects proved conclusively that the clothing of yellow-fever victims was not dangerous.

These experiments conducted by brave men were belatedly acknowledged by the government when President Coolidge in 1929 signed a bill authorizing a gold medal and a life pension to all those living who had participated in the yellow-fever investigations.*

Through application of scientific knowledge about yellow fever, Surgeon-General William Gorgas made possible the digging of the Panama Canal. [See Fig. 21–3.]

Very recent investigation shows that there are at least two other species of mosquitoes beside the Aëdes that can carry yellow-fever virus. Also some of the large tropical animals such as monkeys, opossums, anteaters, sloths, and mice seem to be possible carriers of the virus.

Another mosquito, the Anopheles, carries germs of malaria. Today this disease is more prevalent in tropical regions than is yellow fever. But it is under control where scientific methods are used. The brilliant victory achieved in Brazil through the combined work of the Rockefeller Foundation and the Brazilian government during recent years terminating in 1941,

* Mr. James E. Peabody, former Head of the Biology Department of the Morris High School, New York City, was largely instrumental in the passage of this bill.

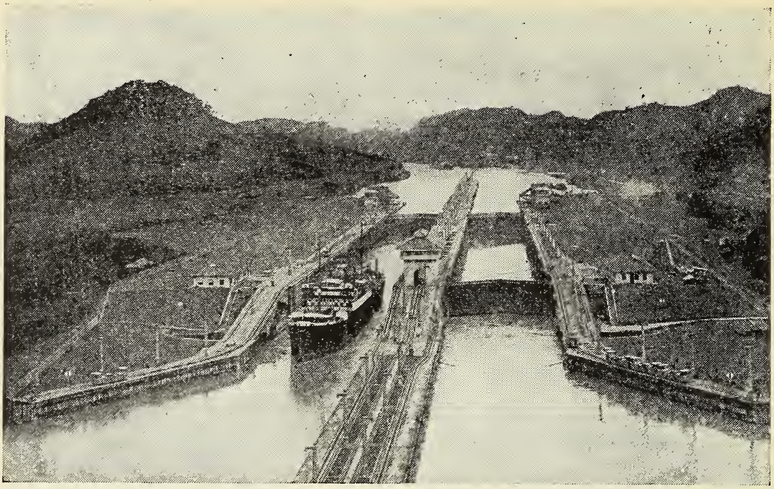


FIG. 21–3. In the great enterprise of digging the Panama Canal, many engineers failed; and our own successful engineers might have failed too, if Colonel Gorgas had not freed the Canal Zone from yellow fever, malaria, and the plague. (*Ewing Galloway*)

wiped out from an area of about 12,000 square miles the last individuals of a particularly vicious form of Anopheles mosquito. This mosquito had been introduced in 1930 from Africa and was causing the worst form of malaria. The mosquito was eradicated by using Paris green in the breeding places and spraying insecticides in buildings.

**462. What can the health department do to reduce diphtheria?** The discovery by Dr. von Behring in 1890 that an antitoxin against diphtheria could be manufactured in the blood of a horse, made possible the first real control of this disease. Before this new treatment the mortality from diphtheria averaged from 30 per cent to 40 per cent and even much higher when accompanied by croup.

In 1929 an intensive campaign of health information in regard to diphtheria and its prevention was begun in New York City. This campaign proved to be so successful that there was an immediate drop in deaths of children. This has continued ever since. In four of the health districts of New

York City, ranging in population from 140,000 to 320,000, there were no deaths from diphtheria for the three years terminating in February 1941, and in one district of nearly 150,000 persons *no death from diphtheria occurred during a recent period of five years.* This remarkable accomplishment can be equalled wherever equivalent co-operation can be attained between public health officials and the local population.

It should be noted that at birth about 90 per cent of babies are immune to diphtheria. Their susceptibility, however, rises rapidly until, during the period from nine months to two years of age, about 75 per cent of children are susceptible to diphtheria. Children who are found by the widely used Schick test to be susceptible to this disease may then receive under the skin an injection of toxoid.

This protective immunization has been given to over 75 per cent of the children of preschool age in New York City. In many communities, toxoid injections are given to all young children whose parents consent, without the formality of a previous Schick test.

**463. What is typhoid fever and how is it spread?** Typhoid fever is associated with filth. It is not caused by dirt, but by typhoid bacteria which, if taken into the body, lodge and grow in the intestines. At an early stage the germs enter the blood vessels and poison the blood of the victim. Typhoid rarely develops under conditions of good sanitation and scrupulous cleanliness. Cleanliness may be, as Alexander Pope said, "next to godliness." It is certainly a basic rule in community health.

In typhoid fever, the bacteria attack the walls of the intestines and the wastes passed off from the bowels contain the dangerous germs. It might become a terrible matter for others if these wastes were thrown on the ground where rain or soil seepage might bring these germs into a well or a stream, the water of which was used as drinking water. In more than one instance, an epidemic of typhoid fever has been traced

to a milkman in whose family there was a single case of this disease. The father, brother, or son — as the case might be — was not careful enough to wash his hands thoroughly, or some contaminated water was left in cans or bottles when they were washed.

Sometimes persons who have recovered from typhoid fever still carry the living germs of that disease in their bodies. Such persons should take special care not to infect others. A few persons, though in apparently good health, are chronic carriers of typhoid germs. A cook known as "Typhoid Mary" was the best known of these cases. She is known to have been the cause of over fifty cases of typhoid fever. The probability is that she unwittingly started many more infections before the board of health learned of her case history and confined her to an institution.

Water and milk are perhaps the commonest sources of typhoid-fever germs. Uncooked foods like oysters taken from sea water polluted by sewage, and salad foods washed, or even watered with polluted water while growing, may thus become infected. The house fly, which breeds in filth and carries germs on its feet, is such a menace that some authorities say that its name should be changed to "typhoid fly."

464. **How prevalent is typhoid fever?** During the Spanish-American war more men died from typhoid fever than were killed in battle. Today, vaccination which is required of all soldiers, and sanitary measures have made this disease a rarity. In the United States, from a death rate of about 16.6 per 100,000 persons in 1900 to 1910, there has been a steady drop to about 2 per 100,000 persons in a recent year.

465. **How do boards of health assist in reducing the number of typhoid fever cases?** Signs are displayed around reservoirs of drinking water warning persons not to pollute the water and, in many cases, not allowing any access to the shores. Precautions are taken that streams of water entering the reservoir do not become infected or polluted. No unsanitary conditions are allowed to exist in territory near the

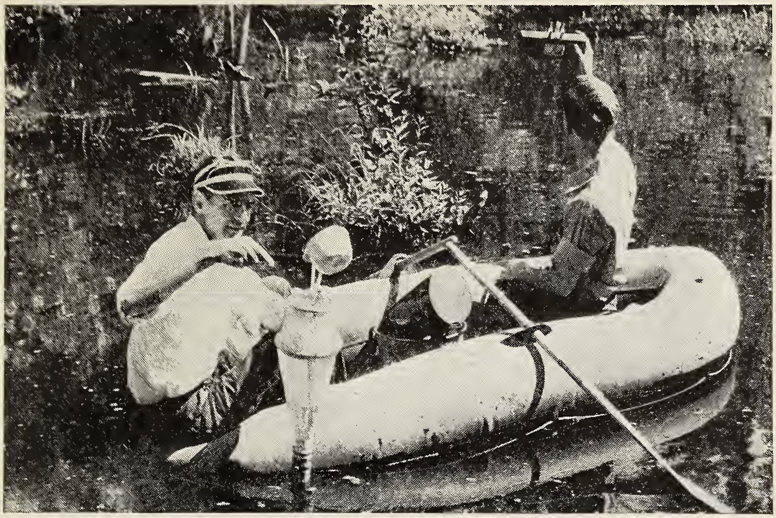


FIG. 21–4. Representatives of the United States Public Health Service are seen here, in a rubber boat, collecting mosquito larvae (left) and testing the purity of the water (right). (*U. S. Public Health Service*)

reservoirs. No swimming is allowed in reservoirs. Bacteriological experts test the water regularly, especially for bacillus *coli* (kō′lī) with which typhoid bacilli are frequently associated. [See Fig. 21–4.] In many communities chlorine is added to the water supply. In most places milk must be pasteurized before it may be sold. It is further tested to make sure that it does not contain dangerous germs. Persons who handle foods are required to undergo thorough physical examinations to detect possible carriers. Foods exposed for sale must be protected against contamination from dust or filth.

466. How was rabies conquered? *Rabies* (rā′bĭ·ēz) or hydrophobia (from Greek words meaning "*fear of water*") was conquered by Pasteur in 1885 when he saved the life of a boy bitten by a so-called "mad" dog.

A rabbit had died of the disease some days before. Pasteur had dissected out parts of the nervous system from the body

of the rabbit and had let these portions dry for several days. He inoculated the boy twelve times with some of this material. The boy recovered because the injected matter evidently caused the development of antibodies or antitoxin in sufficient quantities to overcome the poisonous effects of the virus.

Pasteur had previously experimented on dogs and other animals until he was convinced that this method would be successful with human beings. Yet it must have taken rare courage to dare to use, for the first time, such a novel treatment on human beings.

Today the Pasteur treatment, standardized through long and successful experience, can be secured in practically every large city in the country through the services of the board of health. In some cities there is a special Pasteur institute.

**467. How can rabies be avoided?** Rabies may attack dogs, cats, and sometimes other domestic animals, also wolves and foxes. It is caused by a virus which is usually present in the saliva of an infected animal. Thus from a mad-dog bite some of the virus may get into the blood. Unless checked, the virus attacks the nervous system and causes paralysis and death. The Pasteur treatment is not a sure cure at any stage of the disease. It is rather a preventive of further development of the disease if used promptly after infection has taken place. Early diagnosis by laboratory tests of the attacker's brain is very important.

**468. What is the relation of health departments to rabies?** Most civilized communities recognize the possible dangers from cases of rabies, especially among dogs. The board of health requirement that muzzles be put on dogs when they are at large should be regarded by citizens as a rule of health operating for the good of all rather than as a drastic law aimed to curtail the liberty of our pets. The local or state authorities will quarantine any animal suspected of having rabies and will observe it until either rabies does develop or the animal is considered safe and is freed. In some cases, the department

of health vaccinates dogs in order to render them immune to rabies, and individuals frequently have their dogs vaccinated.

**469. Why must we stamp out tuberculosis?** Most living adults can remember when tuberculosis was called the "Great White Plague" and was dreaded because there seemed to be little hope for its victims. Today we know that if the disease is discovered in time, a complete cure can be expected.

From a social and economic standpoint, tuberculosis is still one of the chief health problems of any community. There are several types of tuberculosis, but the commonest form attacks the lungs.

During the past 75 years or longer, the death rate from tuberculosis has been steadily dropping. But recently, the number of cases has sharply risen in the United States and in England. This rise is probably due to crowded industrial conditions caused especially by the Second World War. Detroit, Michigan, has made an astounding record in lowering their cases by early diagnosis and hospitalization.

**470. How is tuberculosis contracted?** Dr. Logan Clendening, former president of the American Medical Association, has stated that "tuberculosis is a disease especially of poverty, a disease of overcrowding, of insufficient food." He means that when the defenses of the body are lowered by such conditions, then the germs of tuberculosis entering the body are able to get a foothold in the cells and begin to multiply. This may lead to destruction of living tissue so that definite symptoms begin to appear — great fatigue without any special reason, loss of weight, some fever in the late afternoon or evening, and sooner or later a chronic cough. If tuberculosis has actually been contracted, the germs will be found in the *sputum* (spū'tŭm), or in *phlegm* (flĕm) coughed up.

Both Dr. Clendening and another physician even better known — Dr. William Osler — have said that practically everyone at one time or another contracts tuberculosis but

that most persons conquer the infections. Examinations of the bodies of thousands of persons who have died in hospitals and other institutions, show healed spots in the lungs, where the germ once started to flourish, but where white blood cells won out.

*471. Who discovered the germ of tuberculosis? The scientist Robert Koch used a dye which was successful in staining the germs of tuberculosis. Under the microscope he saw rod-shaped bacteria which were later called *tubercle bacilli.* By using this stain he was able to find the same germs over and over again in the infected parts of a tuberculous animal or a person suffering from the disease. He cultivated these bacilli on blood serum mixed with nutrient agar, and then inoculated healthy animals with the bacilli. These animals came down with tuberculosis. Thus Koch not only grew the bacilli of tuberculosis outside the body of an animal; he produced the disease in a healthy animal by injecting these bacilli. The cause of tuberculosis was discovered, and in 1882, Koch announced his conclusive experiments to the world of medicine.

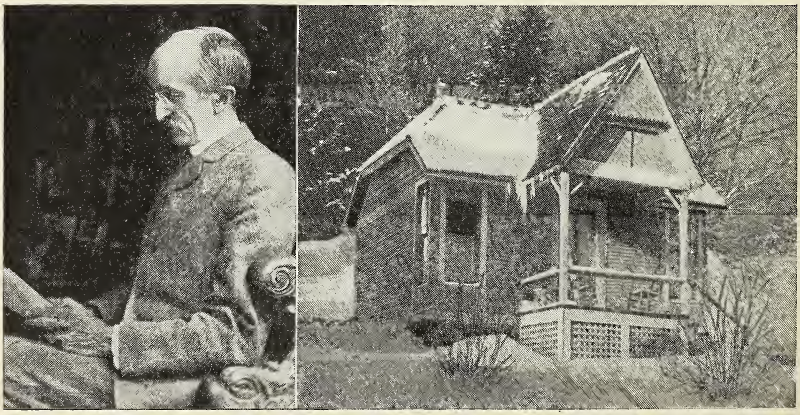


FIG. 21–5. Dr. Edward Trudeau overcame tuberculosis in 1873 by living in this cottage in the Adirondack Mountains. Afterward he founded a sanitarium for the treatment of tuberculosis. (*Courtesy National Tuberculosis Association*)

**472. What treatment is successful in curing tuberculosis?** Not so long ago persons who become tubercular were given remedies such as preparations containing creosote. However, after Edward Trudeau had recovered from tuberculosis by living in the Adirondack Mountains in northern New York and then established a successful sanitarium at Saranac Lake, drugs were abandoned in favor of fresh air and outdoor living. [See Fig. 21–5.] Not only fresh air by day and night, but plenty of good nutritious food such as milk and eggs, is also needed. Investigators learned, too, that tubercular patients grew worse with exercise. So, to fresh air and wholesome food, they added plenty of sleep and rest. Two more conditions were found to be very important: sunshine and a tranquil mind free from worry and, if possible, hopeful.

**473. How can health authorities help in reducing tuberculosis?** Air in mountainous regions is free from dust and may be laden with refreshing odors of evergreens; but fresh air in regions only a little removed from cities may be almost as valuable in treating tuberculous patients. And the accompanying sunshine is just as free here as in the mountains, unless the nuisance of factory smoke is uncontrolled. Sanitaria then can be erected in many convenient places. Visiting nurses representing the health department can either recommend a sanitarium or give advice as to home treatment and suggest precautions so that other members of the family do not contract the malady. [See Fig. 21–6.]

One of the most important health contributions for any community is the establishing of a clinic to which all persons can come for X rays of their chest and for other types of *diagnosis*. Health authorities can also insist upon the enforcement of laws requiring good housing conditions in cheaper tenement buildings; the pasteurizing of milk; sanitary conditions for the sale of foods (including proper certification of the health of persons handling foods); rigid enforcement of the rules against spitting in buildings, cars, subways, and the like, and substitution of the sanitary, flow-

FIG. 21–6. A nurse from the Henry Street Visiting Nurse Service advises a father on methods of safeguarding the health of his children. (*Courtesy Henry Street Visiting Nurse Service*)

ing, drinking fountain for the common drinking cup. A heavy responsibility rests upon health officials to inform all persons in their locality about the characteristics of the disease, the ways of contracting it, and particularly the best program to be followed in curing it.

**474. Can vaccination prevent tuberculosis?** Dr. Koch developed a liquid which contained tuberculosis toxins and which he called *tuberculin.* By inoculating persons with tuberculin, Koch hoped to immunize them. However, neither he nor anyone else has ever succeeded in producing immunization by the use of tuberculin. Instead, it is now used as a diagnostic test, called the Mantoux test. A small quantity of very dilute tuberculin is injected into the skin with a fine needle. If there are no tubercle bacilli in the body, there will be no reaction. If, however, within a period of two to

three days, there develops around the point of injection a red, inflamed area, this indicates that there are living tubercle bacilli within the person's body. This does not necessarily mean that the person is suffering from active tuberculosis, though this is sometimes true.

In France, Dr. Calmette developed and used weak vaccine cultures of living tubercle bacilli, generally called B.C.G. Hundreds of thousands of babies have been inoculated with B.C.G., but more time is needed to watch the results.

**475. What is the general situation with regard to tuberculosis?** A half century of research has failed, as yet, to produce a specific remedy that will heal tuberculosis. Our knowledge has greatly improved regarding the best way to help the patient's body and mind to cope with the disease. As in so many other diseases, early diagnosis is of the greatest importance.

Although the number of new cases of tuberculosis has been steadily declining for about 75 years, *the ratio of deaths to cases has not declined.* Among females, tuberculosis is still the chief cause of deaths between the ages of 15 to 35 years; among males it is the chief cause between the ages of 20 and 35. The danger from tuberculosis reaches its peak during the first five years of life and again during the twenties.

**476. What should health authorities do about sanitation?** Sanitation literally is public health. The word is derived from the Latin *sanitas* meaning *whole, sound.* By general usage, however, the work of a sanitary bureau usually has to do with cleanliness of food and of streets; the prevention of undue dust, smoke, and objectionable odors; the removal of garbage, ashes, and rubbish (including dead animals) from streets; the preservation of drinking water from contamination through defects in plumbing or other toilet facilities; the maintenance in cold months of at least the minimum of heat required by law in tenement houses; the abatement of unnecessary noises; and many, many other duties and responsibilities varying with different communities.

The inspections necessary to insure absence of pollution of reservoirs, of drinking water, and of waters used for public bathing, as well as the control of obnoxious insects such as flies and mosquitoes, are matters for sanitary engineers.

**477. How can health officials safeguard food?** During recent years competition among manufacturers in respond-

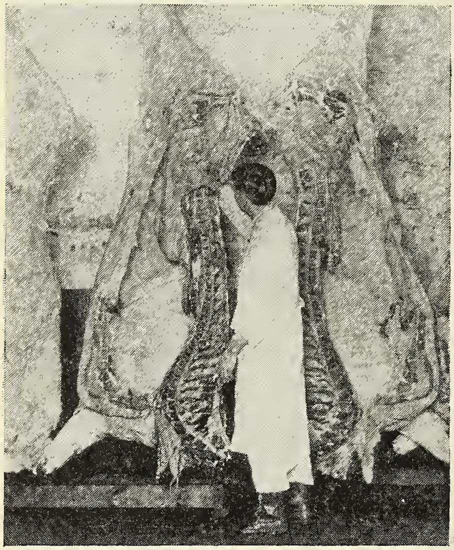


FIG. 21–7. The United States Government maintains inspectors who must certify to the healthfulness of meat before it is allowed to be sold to the consumer. The government stamps accepted meat with a purple stamp. Look for this stamp the next time you are in a meat store. (*Courtesy Armour and Co.*)

ing to a popular demand for the careful wrapping of food has resulted in almost perfect packaging of many articles such as cereals, dried fruits, sugar, and spices. [See Fig. 21–7.]

However, some storekeepers who sell vegetables, fruits, and perishables like butter and cheese, are not particularly careful to keep these things properly cold and under cover to prevent the accumulation of dust.

In cities, the pushcart and the wandering horse-drawn wagon dispense many kinds of commodities, from vegetables and fruits to many kinds of cheap candy, soft drinks, or frozen foods. Some of the larger and more reputable ice-cream companies send out uniformed salesmen who handle their superior products in an entirely hygienic and satisfactory manner.

However, the vendor of low-grade ices and unwrapped colored candy may easily be distributing disease and even death with his goods. He himself may be diseased. It is difficult for health officials to check on every vendor.

In large cities, persons desiring to become employees at soda fountains, in restaurants, and in hotels must pass a health examination before securing such positions. However, this is not a uniform requirement in such establishments throughout the country; it seems to depend upon the alertness of the health officials of each locality.

In New York City the Department of Health controls the sanitary conditions of about 150,000 concerns which sell, store, or manufacture foods and drugs. The laboratories of the Department of Health also analyze many samples of patent medicines and drugs.

The supervision of the milk supply of any locality is one of the most important functions of health officials. Formerly milk in bulk (loose milk) was sold in grocery stores and even peddled. Today the general practice is to deliver milk carefully protected either in sanitary bottles or in sanitary packages. In most communities in this country, milk is pasteurized. New York City probably exercises greater care in the supervision of its milk supply, drawn from seven states and from regions as far as 400 miles distant, than any other city in the world. [See Fig. 21–8.]

Tests called *phosphatase* (fŏs′fȧ·tās) field tests are made by inspectors in order to check the thoroughness of the pasteurization of milk and cream. This test is so delicate that in a few minutes the inspector can determine the addition of less than 1 per cent of raw milk to the pasteurized milk, the slightest lowering of temperature in pasteurization, or a reduction of even a few minutes in the time of pasteurization.

In addition to the phosphatase test, milk destined for New York City, upon arrival at the receiving stations in the country, is tested for temperature, odor, and sediment. Samples are also sent to the bacteriological laboratories of the Depart-

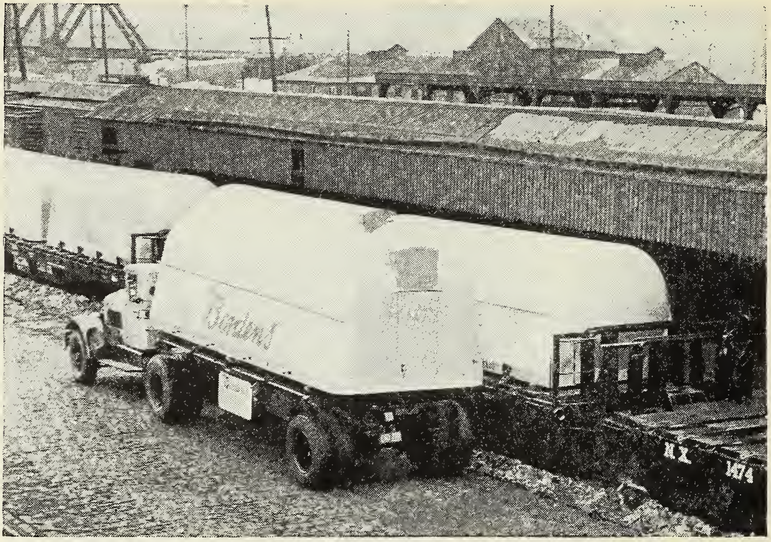


FIG. 21–8. Milk is brought into New York City from distances as great as 400 miles, in stainless steel refrigerated railroad tanks. In the railroad yard, each tank is transferred from the flat car to a motor truck for delivery to local pasteurizing plants. (*Courtesy The Borden Co.*)

ment of Health to determine the bacterial count in the milk. The procedure is simple. The sample of milk is diluted with sterile water. Then a certain amount of the mixture of milk and water is placed on nutrient agar in Petri dishes. These dishes are then let stand at a standardized temperature. At the end of a previously determined period, the number of bacteria colonies, if any, are counted. Any indication of poor quality of milk means a special inspection of the dairies concerned.

There are regular inspections of dairies for violations of the sanitary code. In addition, in many states, cows supplying milk for the public are tested by the tuberculin test for the possible presence of tuberculosis. The tuberculin test was unsuccessful as a cure for tuberculosis, but it did prove to be a method of indicating tuberculosis both in human beings and in cattle. Toxins from tuberculosis germs are injected

under the skin of the cow. If the cow is tubercular, the area around the injection becomes somewhat inflamed. Cows that are thus shown to be diseased are killed, and the farmer who owned them is paid by the state.

**478. How can the purity of drinking water be assured?** The purity of the drinking water of any community today is one of the most important responsibilities of health officials. There are several methods of ensuring safe drinking water. Among these methods are filtering the water, aërating it, boring deep wells so that the water will be uncontaminated, and treating water with chlorine or in some cases with copper sulfate. Whatever the method of providing safe drinking water, biochemists or other experts test the water at intervals to ascertain its freedom from disease-producing bacteria.

***479. Why should there be a laboratory connected with every department of health?** There is hardly a communicable disease that does not call for certain microscopic examinations at some stage, or the experimental check of such tests as the Schick test for diphtheria and the Dick test for scarlet fever. In addition, X rays are taken in the diagnosis of tuberculosis, infected teeth, broken bones, and other derangements. Sputum and blood tests must also be made for many afflictions. In the larger laboratories vaccines and antitoxins are produced.

Smaller and widely scattered communities cannot afford to maintain such laboratories. They are handicapped by the necessity of sending specimens for examination to the nearest laboratory. Small traveling laboratories have been found to be exceedingly valuable. Some of these medically equipped automobiles hold as many as 24 clinics a week.

In addition to all the foregoing more or less routine work, much scientific research of a medical character can be carried on in a well-equipped and directed laboratory. New methods of immunization against contagious diseases, checking the efficiency of new serums, analyzing the causes of special outbreaks of diseases like influenza or measles, and other similar

FIG. 21–9. Hikes in the open air and other forms of outdoor life contribute to a happier youth and serve as a preventive for disease of the lungs. (*Courtesy American Youth Hostels, Inc.*)

procedures occupy the attention of trained men and women.

**480. How has public and private opinion changed with respect to the treatment of disease?** The realization of the value of sunshine and fresh air has completely altered the method of treating tuberculosis and pneumonia. [See Fig. 21–9.] Children suffering from certain types of tuberculosis are now sent outdoors to receive all the rays of the sun possible on their bodies, even in winter. Formerly this treatment would have been considered as a crime against children. Victims of pulmonary tuberculosis were formerly " protected " from fresh air and open windows. Today such a person literally lives out of doors, day and night. The windows of rooms where there are victims of pneumonia likewise now are kept wide open, the patient being protected from exposure. Not so very long ago, however, this procedure would have been considered madness. For hundreds of years malaria was considered to be a disease which originated in swamplands and marshes, as the very meaning of the word " bad air " implies. Now we search for guilty mosquitoes.

Insane persons were quite likely to be chained to posts or trees and frequently had to suffer physical punishment. Nowadays a psychiatrist tries, or should try, to remedy mental derangements when they begin and are only small beliefs. The hopelessly insane are cared for in well-equipped institutions where medical, physical, and mental care is given.

A balanced diet is particularly important. Formerly the quantity of food was emphasized rather than the relative amounts of nutrients and vitamins. Dr. McCollum of Johns Hopkins University has shown that there is a definite relationship between tooth decay and the lack of sufficient vitamin C in the diet. Other experimenters have proved that the subject of vitamins is perhaps the most complex and important phase of diet and health.

**481. How can the level of community health be raised?** Any community can, within reason, realize about as high health standards as it wants and is willing to pay for.

Many communities have taxed themselves in order to maintain visiting nurses, health inspectors, laboratories for tests and experiments, clinics for consultation and diagnosis, and one or more hospitals for the adequate care of those who are ill or who have been injured. The citizens have found that these provisions are in effect good insurance for every member of the community.

**482. How can health education be made more effective?** If health officials are to be the most effective, they should not appear to be dictators, but rather to be teachers and leaders in the community. The proved facts, if presented by announcements in newspapers, by reports of lectures and meetings, by the distribution of pamphlets and printed material, and by posters, placards, and notices, are convincing. Dr. Bolduan, Director of the Bureau of Health Education in the Department of Health in New York City, said recently, in connection with the reduction of deaths from diphtheria, "We can credit this reduction to health education because the protective inoculations were not compulsory in this city."

It should be noted that health instruction in public schools has probably been the most effective means of basic education in these matters.

**483. How important is the mental attitude of the citizens?** Most persons act as though they regarded their bodies as their essential selves. They feed, clothe, and clean the body; they have pictures taken of their faces, saying, "That is a photograph of me"; they find that "they" are gaining or losing weight; they feel happy or depressed according to the amount of freedom from bodily complaints.

Yet the real personality is more mental than physical. Happiness or depression is fundamentally a state of mind. The person who cultivates a hopeful, cheerful, and constructive attitude toward life is contributing heavily toward a longer life and a healthier one.

When the influenza epidemic of 1918 was at its height in New York City, the Health Commissioner received a demand from representative citizens that he close the schools and churches. He refused to do so, saying that a great increase in cases would inevitably follow because of the widespread hysteria which would develop if he took such action. He knew that public health is, largely, multiplied private health.

Often the first thing a good physician does when visiting a patient is not to give him medicine, except in cases of emergency, but to allay his fears so that the treatment he prescribes later will be more successful. One of the best-known physicians in the world, Dr. William Osler, in his article on "Medicine" in the *Encyclopedia Americana*, said this: "Faith will enable a bread pill (*placebo*) or a spoonful of clear water to do almost miracles of healing when the best medicines have been given over in despair. The entire profession of medicine is faith in the doctor, in his drugs, and in his methods."

**484. What can health officials do in connection with mental hygiene?** Fear, suspicion, misunderstandings, and resentment in children warp both body and mind. Abnormal attitudes of mind may become fixed and later in life lead to

mental disturbances. This is a much more serious matter than is realized by most persons. Specialists in mental hygiene say that about 4½ per cent of the children in any community will at sometime in later life be sent to an institution for treating mental disease.

This is appalling. It means that in a school of 1000 pupils, 45 will, if present statistics hold, at some later period need treatment for mental disorder. Many of these unfortunate cases could be adjusted and cured in early stages by consultations with understanding specialists. In a very few schools a psychiatrist – that is a person who searches the *psyche* (sī'kė) or mind – is employed to help children to make mental adjustments where necessary. Adults too, who have had to face terrific problems, frequently need the help of experienced advisers. Mental clinics are as needed as are the medical clinics so prevalent today.

The solving of mental problems while they are small and not fixed will give the country sounder citizenship and save every community money because there will be fewer asylums, less crime, and better health.

## QUESTIONS

1. What are some differences between individual health and community health?
2. What officials or organizations are responsible for the maintenance of public health in your locality?
3. Why should more emphasis be put on the prevention of disease than on the curing of disease?
4. How do public health officials work in different ways to keep some particular disease under control? Give an example.
5. Why is cholera not the dreaded "black death" today?
6. What methods are employed to prevent epidemics of plague?
7. What is the dramatic story of the conquest of yellow jack?
8. What can health officials do to reduce diphtheria?

9. What is typhoid fever and how is it spread?

10. How can typhoid fever be controlled?

11. What is the relation of tuberculosis to community health?

12. How can health officials reduce the number of cases of tuberculosis?

13. How can health officials function in the matter of sanitation?

14. How are food products safeguarded in a community by public health officials?

15. How is milk inspected, tested, and protected from producer to consumer?

16. Can you mention all the ways by which pure drinking water can be obtained for a community?

17. Of what particular values may an experimental laboratory be if connected with a department of health in a community?

## *Some things for you to do*

1. Arrange for a visit to the headquarters of the board of health of your community. After such a visit, write an account of your trip for your school paper under an appropriate title such as "What Our Board of Health Does."

2. If you have never visited a pasteurization plant, try to get permission to make such a visit. Also read about the methods of handling milk, then write an article on "Milk, from Cow to Icebox," showing how milk is continuously safeguarded.

3. Find out how the drinking water of your communiy is purified. If possible, consult representatives of the board of health to find out just how pure water is obtained.

4. Consult the vital statistics of your community and make a poster graph showing the prevalence of two or three well-known diseases such as diphtheria, tuberculosis, and measles during a given period, such as a recent period of ten years. Explain drops in the graph below normal, also rises in the graph above normal.

# *Man Has Developed New Types of Plants and Animals*

WHEN men appeared on the earth and eventually gathered in clans or tribes for protection and mutual assistance, they found that many of the wild plants were suitable for food and for making articles. Men must have selected some of these desirable plants and transplanted them to places nearer their caves or huts. Thus the earliest and most primitive gardens originated. Once having cultivated special plants, it must have been an easy step to the selection of the best plants for the improvement of their gardens. Through man's selections, the types of plants were somewhat altered and improved, very slowly, but more quickly than in nature.

At some remote time, one of these early men must have caught a young wolf or fox and succeeded in partly taming it. We are now sure that it was from a wolflike or foxlike ancestor that man obtained his first domestic animal, the dog. Then, later, by selection and breeding, man developed the different varieties of dogs seen today.

Thus we see that changes in plants and animals have occurred in nature and that even greater changes have been brought about by the selective desires of man. During the present century, the greatest advances in plant and animal breeding have taken place. The discoveries of the laws of heredity by Mendel brought order into a field of chaotic ideas. The Mendelian principles have completely revolutionized breeding practices. Also experimental biology has shown that X rays and certain chemicals can play their part in giving to the world new types of organisms.

## *THINK ABOUT THESE!*

1. What is a chromosome and how important is it?
2. Why do nasturtium seeds always produce nasturtiums?
3. New kinds of plants and animals have occurred in nature. Can man bring about such changes in organisms?

## *WORDS FOR THIS CHAPTER*

**Heredity.** The likeness of offspring to their parents or to their family line.

**Chromosome.** One of the divisions of the chromatin in the nucleus of a cell, concerned with the heredity of the animal or plant to which it belongs.

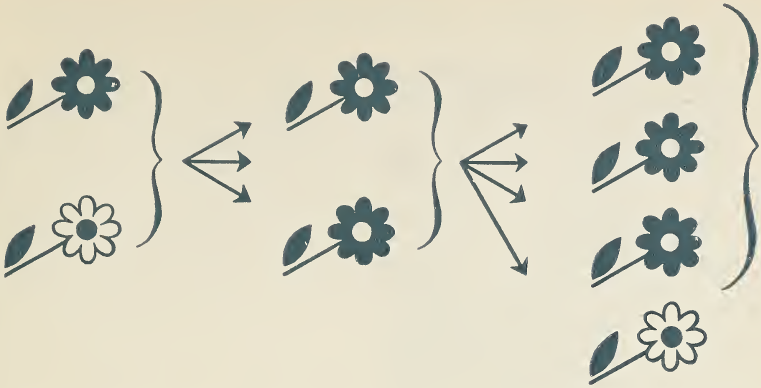
**Gene** (jēn). A part or region of a chromosome believed to be the physical basis for the hereditary characteristics of the offspring.

**Dominant.** A character that appears to overbalance its opposite, which is a recessive character.

**Recessive.** A character that is apparently overshadowed and suppressed by a dominant character.

**Hybrid.** The offspring from two parents differing in a hereditary character.

**Genetic** (jė·nĕt′ĭk). Relating to heredity.



*CHAPTER 22* ——————— *UNIT 12*

# *What Do We Know about Heredity?*

**485. Do fossils in rocks resemble present-day plants and animals?** At some time you may have seen fossils of shells or other forms in sedimentary rock. If you knew enough about the study of ancient life, you would be able to show both likenesses and differences in comparing such fossils with modern organisms. If the fossil you found was a shell, it was probably something like a clam or a scallop shell, but smaller and with a different kind of hinge. The likenesses show that the living forms of today are related to these old types, of which your fossil was an example. The organisms of today must be the descendants of prehistoric ancestors. Life begets life, and no scientist has yet made a living form. The differences between the fossil and living organisms mark changes that have occurred through the ages.

**486. Has anyone ever seen changes occur in plant or animal forms?** Out in the western states there is a bird called the ptarmigan (tär′mĭ·găn) which resembles a chicken. The feathers of this bird become almost pure white in the winter

FIG. 22–1. The varying hare is one of the few animals that change color in the winter. The white winter coat of this hare colors it protectively for snowy regions. (*U. S. Dept. of Interior, Fish and Wildlife Service*)

time. In the northern states and in Canada the varying hare, a big rabbit, also changes the color of its coat to white in the winter time. [See Fig. 22–1.]

**487. Are there different kinds of changes in plants and animals?** Some of the many changes in organisms are effects of the environment, such as variations in food, temperature, or moisture, for example. In such cases, the color, size, and quality of individual plants and animals may be more or less altered. Their offspring will not, however, be affected unless they are exposed to the same conditions.

Other changes in organisms are inherited by the offspring. These might be called *hereditary* changes. How such changes come about and the part that man plays in the production of desirable new types of plants and animals is a story of modern magic, which will be taken up in this chapter.

**488. How did the ancients think that new organisms arose?** Of course the ideas of early man on almost any subject displayed both deep ignorance and almost universal acceptance of superstitious beliefs. Even Aristotle, the first zoologist, in his remarkable book *Historia Animalium,* written more than two thousand years ago, said, "Most fish originate in mud and sand." An English writer of the sixteenth century, Gerard, shows a picture of barnacles from whose shells, as he states, geese emerge. This superstition lasted long

enough to give us the term "goose barnacle," applied to certain barnacles today. Until recent times, many peoples have believed what Alexander Ross wrote: ". . . Go to Egypt and there find the fields swarming with mice, begot of the mude [mud] of Nylus [the Nile]."

Although the scientific advances of the modern civilized world have corrected such errors, there are millions of primitive peoples in the world today who believe that the earth is flat; that the sun moves around it; and that man and his flocks and plants are under the control of spirits and gods, some good and others bad. Such peoples know next to nothing about modern science. Even in civilized society, many persons believe that toads bring warts to those who handle them; that snakes, supposedly killed, do not die until sundown; and that so-called "horsehair snakes" develop from some long hairs dropped from a horse's tail into stagnant water.

Science is steadily though slowly bringing truth into the minds of mankind. Boys and girls today, through science courses in school, through varied information given over the radio, and through books and magazines, have much more knowledge than primitive man had; also, they know something about the method of science. They know that *the scientific method* means always desiring the truth. It means solving problems by experimenting; using enough data to prevent mistakes in judgment; checking and rechecking for accuracy; and finally accepting and acting in harmony with the proved results. If the scientific method could become a habit with all of us, all persons could be trusted. Do you feel that you have a responsibility to practice the scientific method?

**489. What do we mean by heredity?** If you are planting a flower garden, you know that in a few weeks the growing seedlings will show by their characteristics what kinds of seeds were planted. Aster seeds will never produce nasturtium plants, nor will zinnia seeds grow into pansies.

The law of *heredity* functions; like produces like. Thus

offspring, of both individual plants and animals, with few exceptions, more or less closely resemble their parents.

**490. Why do most offspring resemble their parents?** You already know that a new individual, whether plant or animal, usually is produced because a little protoplasm from the nucleus of a sperm cell unites with some of the protoplasm of an egg cell.

The male parent furnishes the sperm cell, and the female parent furnishes the ovum, or egg cell. The union of these bits of protoplasm is called fertilization and results in a fertilized egg. And from this fertilized egg, even though it may be almost microscopic, comes the new individual, which may become a Sequoia towering 300 feet high, or a fly almost as small as the point of a pin.

Since the new individual arises by the continued cell division of the original egg cell, one must search in the protoplasm of the sperm and the egg for the secrets of heredity.

**491. What structures are concerned with heredity?** If we examine slides of stained reproductive cells, prepared in biology laboratories, we can see curious things in the nucleus of each of these cells. This, of course, requires very great magnification by the use of a microscope. The nuclei may look somewhat like long wires or like shorter pieces of wire, each bent into a loop. Such structures show staining more brilliantly than does the rest of the cell.

If the cell you examine is a young cell not ready for reproduction, instead of these bent pieces you will probably see what looks like a tangle of thread in the nucleus. This is called *chromatin,* from *chrome,* meaning *color.* Later, when the cell is ready for reproduction, this chromatin breaks up into the short lengths just referred to, each shaped somewhat like a capital letter U. Each of these short lengths is called a *chromosome.* These chromosomes are found not only in the nucleus of these reproductive cells; they are also found in the nucleus of every other cell of the particular animal or plant you are considering.

492. How do chromosomes behave when a cell divides? Growth in a plant or an animal is the result of the formation of many new cells. But growth is not merely a matter of simple increase in size. It involves complex changes in the internal structure of cells. When a new cell is formed, each of the chromosomes becomes shorter. Then they all come together across the middle of a spindle of threads. Each chromosome now splits and separates.

When the two groups of chromosomes are in opposite parts of the cell, a wall forms across the cell halfway between them. Each half of the cell, with its particular group of chromosomes, now becomes a separate cell divided by the membrane in the middle. Around each group of chromosomes another wall forms, thus completing the nucleus for the cell. Now there are two cells where there was one before, each with a nucleus containing similar chromosomes. [See Fig. 22–2.]

This complex process is called *mitosis* from the Greek *mitos*, meaning *thread*. It occurs all the time in all growing cells.

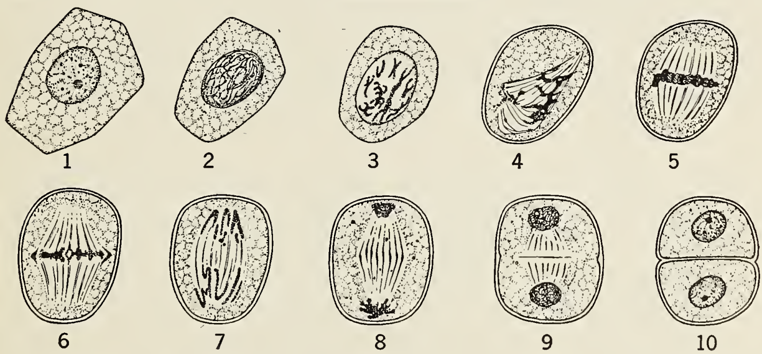



FIG. 22–2. 1. Normal cell. 2. Chromatin material of nucleus gathering into strings. 3 and 4. Strings dividing into short lengths, or chromosomes. 5. Chromosomes gathering across middle of cell. 6, 7, and 8. Each chromosome dividing; one half going to one end of cell, and the other half going to the other end. 9. Division line beginning to form between two groups. 10. Middle wall dividing cell into two complete cells. In each, the ball of chromosomes becomes the nucleus. (*From original studies of cell division in pollen, drawn by Paul B. Mann*)

493. Are the numbers of chromosomes constant in all cells of a given plant or animal? By patient investigation it has been found that there is the same number of chromosomes in each one of the millions or billions of cells, except in the reproductive cells, of any particular organism. In the frog, each of the body cells has 26 chromosomes. The garden pea has 14 chromosomes in every cell of root, stem, and leaf. You, as a human being, have 48 chromosomes in each of your body cells. A house fly has 12, a mosquito 6, a chicken 18, and a monkey 48. Biologists know the chromosome number of many other organisms.

However, early investigators were greatly concerned about one matter. How was it that the tadpole, for instance, an offspring of the frog (having 26 chromosomes) also had 26 chromosomes? Since the egg cell of the frog contains 26 chromosomes and the sperm cell likewise has 26 chromosomes, it would seem likely that the union of these two cells would give a fertilized egg cell having 52 chromosomes; that is, twice as many as each of the parents.

Long study with the microscope revealed the secret. When the male frog forms sperm cells and the female frog forms egg cells, there occurs an interesting change from that which occurs when other cells are formed in the body. Each of these chromosomes *fails to split into halves* as in the formation of new body cells. Instead, half of the 26 chromosomes gather at each end of the cell and constitute the nucleus of a new cell. Thus, instead of 26 chromosomes only 13 are now present. This formation of new reproductive cells with half the normal number of chromosomes is called the reducing division, or *maturation*, from the Latin *maturare — to become ripe*.

When fertilization takes place, there is thus a union of the 13 chromosomes in the frog egg with the 13 chromosomes of the frog sperm. The two kinds of " half cells " have joined, and the resulting fertilized egg cell now has 26 chromosomes. Thus the tadpole comes to have the same number of chromo-

somes as the cells of each of its parents. This same reduction to one-half the normal number of chromosomes occurs in the formation of egg cells and sperm cells in all animals and plants that reproduce sexually.

494. **What is the chief function of the chromosomes?** Since the reproductive cells are the only living parts contributed by the parents to their offspring, and since the nucleus of cells has long been known to be the most important part of any cell, it seems likely that heredity or likeness of offspring to parents must be associated with these cells. The chromosomes of the reproductive cells have long been considered the key to the riddle.

Biologists during recent years have come to believe that a chromosome is made up of tiny parts, each being responsible for a particular trait or characteristic of the offspring. Each of these parts or regions of a chromosome is called a *gene.* Thus the hundreds of physical characteristics of an individual, such as color and texture of hair, facial appearance, height, color of skin, are each predetermined by a gene for that character. While no one has yet seen a gene, Professor Thomas Hunt Morgan, formerly of Columbia University, and his stu-

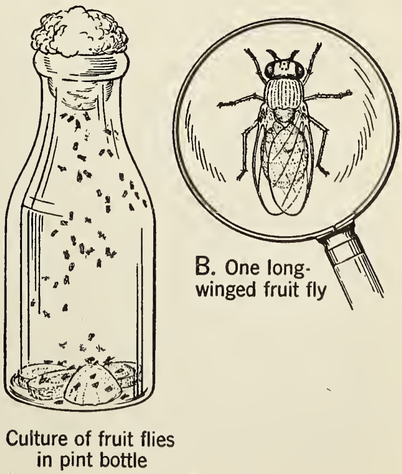



FIG. 22–3. The fruit fly has been studied more intensively by biologists than has any other animal. It reproduces rapidly, and it is easily cultured in a bottle with pieces of banana for food. It is especially interesting and useful because it is subject to frequent mutations. These help scientists to determine what changes may come about in living things.

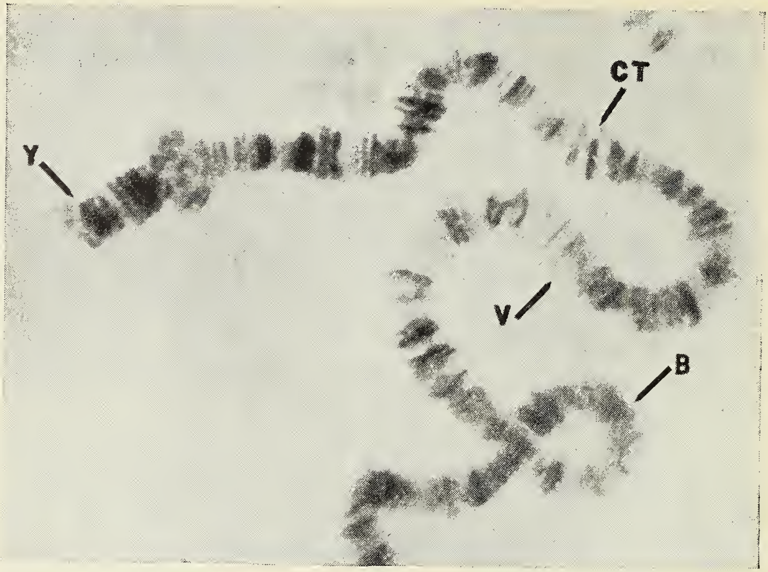



FIG. 22–4. The chromosomes of the cells of the salivary glands of the fruit fly are more than one hundred times as large as ordinary chromosomes. One of these chromosomes is shown here, greatly magnified. Note the dark bands. Each of these regions has been shown to be associated with different genes, each determining a character in the offspring. Four of these regions are labeled. Y has to do with yellow color; CT refers to cut-wing, V means vermilion color, and B relates to bar-eye.

dents have located regions in chromosomes and labeled the genes which they think are found there.

In 1932 Professor Painter discovered that the chromosomes of the cells of the salivary glands of the fruit fly were large in size and showed definite bands. While no one dared to say that these bands were genes, experiments proved that certain bands or parts of bands were associated with types of eyes, wings, and color. Biologists have studied heredity in the fruit fly more than they have in any other animal. They are greatly helped by the fact that there may be as many as twenty-five generations in a year. [See Figs. 22–3 and 22–4.]

Remember that although the number of chromosomes in a cell of any particular plant or animal is relatively small and constant, there are hundreds and even thousands of genes in such a cell. These are believed to determine, in large part, what an organism will be like when it develops into an adult.

**495. What is the relation of chromosomes to sex?** Modern biology has found that the sex of any offspring, plant or animal, is determined, with very few exceptions, at the moment of fertilization. Although, as we have said, the number of chromosomes is fixed for each organism, many of the sperm cells of organisms lack one chromosome, the X chromosome. What occurs when a sperm cell in which one chromosome has been omitted unites with a normal egg cell? Such an egg develops into a male. Eggs fertilized by sperms with the full number of chromosomes develop into females. *An egg that normally would make a female individual is turned into a potential male because of a missing chromosome.*

**496. Who was Gregor Mendel?** At the time of our War between the States, an obscure monk named Gregor Mendel lived in Austria. He had a garden of his own in the monastery at Brünn. Here he enjoyed trying various experiments, mostly with garden peas. By careful examination he noted seven pairs of contrasting characters among his peas.

**497. What experiments did Mendel make?** This monk was particularly interested to see what kind of seeds and subsequent plants would result if he took pollen from flowers of a pea plant producing nothing but yellow seeds (that is, a pure character of yellowness) and put it on the pistil of flowers on a pea plant producing nothing but green seeds (that is, a pure character of greenness). Actually, Mendel himself caused cross-pollination between these flowers, instead of letting bees do it in a haphazard manner. To his surprise he found that all of the seeds produced by his artificial cross-pollinations were *yellow*, although they were on a plant normally producing green seeds. He cross-pollinated flowers of peas normally short, with pollen from flowers of peas nor-

mally tall and got seeds which when planted produced nothing but *tall* plants. He tried a third combination: pollen from flowers of plants grown from smooth-seeded peas placed on flowers of plants grown from wrinkled seeds. All the seeds thus produced were *smooth.* He tried experiments concerned with the four other characters, and in all seven cases he found that the offspring resembled only *one* of its parents as will be seen in the following table.

In each case, one of the two characters, or " factors " according to Mendel, seemed so much more evident than the other that Mendel called it a *dominant character.*

| Pairs of Contrasting Characters of Peas Used in Cross-pollination | Character Dominant in the Offspring |
|---|---|
| 1. Yellow seeds and green seeds | Yellow seeds |
| 2. Smooth seeds and wrinkled seeds | Smooth seeds |
| 3. Tall plant and short plant | Tall plant |
| 4. Colored seed coat and white seed coat | Colored seed coat |
| 5. Expanded pod and constricted pod | Expanded pod |
| 6. Green pod and yellow pod | Green pod |
| 7. Flowers on sides of stem and flowers at ends of stem | Flowers on sides of stem |

**498. What is Mendel's law of dominance?** By continued experiments Mendel found that the offspring resulting from a mating of two plants, each with a contrasting character, was apparently completely dominated by one of the characters. He called this discovery the *law of dominance.* But he also found, as we shall soon see, that the offspring that seemed to have only this one character, also had the other character, suppressed but not lost. This character which did not show he called the *recessive factor.* The offspring coming from the crossing of two pure characters he called $F^1$, meaning " first *filial* " (son) *generation.* He also used the word *hybrid.* To-

day we also call such an offspring a *half-breed:* although in appearance it apparently resembles only one parent, its chromosomes show genes from both parents.

Mendel also discovered the laws of segregation and of unit character, which are considerably harder to understand than is the law of dominance.

**499. How many combinations are possible?** It should be easy to see why offspring are never exactly like their parents. Man has 48 chromosomes (24 pairs) with thousands of genes. In human heredity, there are many millions of possibilities for different genetic combinations. So in human beings, *pure race* is impossible, although a person may possess some of the prominent characteristics of a certain group.

***500. Do the laws of Mendel apply to all plants and all animals?** The laws of Mendel have been found to apply al-

SOME DOMINANT AND RECESSIVE CHARACTERISTICS

| | Dominant Character | Recessive Character |
|---|---|---|
| *Plants* | | |
| Summer squash | White fruit | Yellow fruit |
| Cotton | Colored fibers | White fibers |
| Wheat | Susceptibility to rust | Immunity to rust |
| *Animals* | | |
| Guinea pigs | Black coat | White coat |
| | Rough coat | Smooth coat |
| | Short hair | Long hair |
| Sheep | White coat | Black coat |
| Cattle | Hornlessness | Horns |
| Horses | Trotting | Racing |
| *Human Beings* | | |
| | Baldness | Normal hair |
| | Stoutness | Normal size |
| | Normal sight | Red-green color-blindness |
| | Normal speech | Deaf-mutism |

most universally to plants and animals, including many characters of human beings, so far as they have been investigated. Biologists are continuing such research at the present time.

However, for several reasons it is not so easy to reach conclusions regarding Mendelian laws in the case of human beings. It is difficult to isolate pure characters; human beings have relatively few offspring; there are nine months between fertilization and birth; and the slow development to maturity requires from a quarter to a third of the life span, approximately from 18 to 20 years. Thus our knowledge of human heredity is not so exact as in the case of many other animals and of the plants as well. The table on the preceding page represents some of the latest information as to dominant and recessive traits in plants and in animal organisms.

***501. Exceptions to Mendel's law of dominance.** In some cases Mendel's law of dominance does not seem to apply. In the case of a plant called the *four-o'clock*, a specimen bearing pure red flowers, if crossed with another specimen bearing white flowers, will form seeds which will produce, when planted, plants with pink flowers. Pink is a color blended between red and white. Such an occurrence is called *incomplete dominance*. [See Fig. 22–5.]

A certain species of Spanish poultry called the *Andalusian fowl* also shows blended color in its chicks. The mating of a

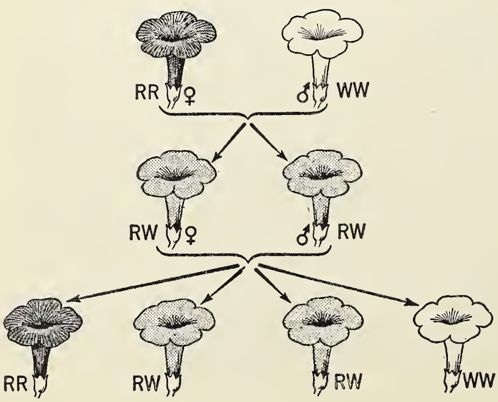



FIG. 22–5. If a four-o'clock plant bearing red flowers (RR) is crossed with a plant bearing white flowers (WW), the resulting seeds will produce pink hybrid flowers (RW). These hybrids, crossed, produce offspring in the ratio of one red, two white, and two pink hybrids.

black rooster of this species with a whitish hen produces chicks with bluish or grayish plumage.

In human beings, the characters of body size, height, weight, skin color, and shape of head are a few of the characters which are likely to blend instead of following Mendel's law.

**502. What are mutations?** Between fifty and sixty years ago, a Dutch botanist named Hugo De Vries found in his gardens, in a group of evening primroses, several plants which were quite different in certain particulars from the normal species he had been growing.

De Vries, greatly interested, carefully examined, during a period of several years, 50,000 specimens of evening primroses. He found that there were as many as 800 variant plants. In 1901 he coined a new word, *mutant,* from the Latin *mutare,* meaning *to change.* He applied the new word to these new and different forms. Men had seen variations in moisture, food, light, and other conditions produce startling changes in plants and animals. But such effects were not inherited. These mutants of De Vries were different because the new characteristics were inherited.

Biologists who accepted his theory began to ask, "Why do mutants occur?" Is there a scientific cause for such freaks which up to the time of De Vries had been casually noticed and called merely *sports?* While searching for the scientific

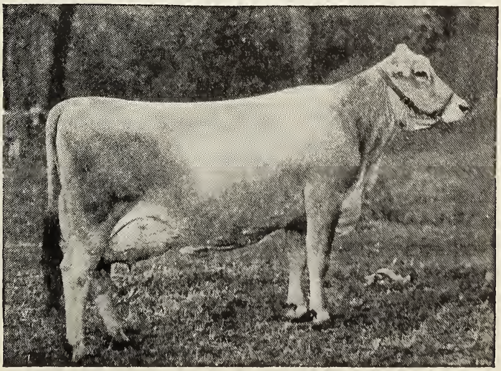


Fig. 22–6. Hornlessness among cattle seems to be a definite mutation. It began with the sudden appearance of a hornless bull among cattle that had horns. (*Courtesy The Borden Co.*)

answer to the riddle, several cases of mutants came to light. In recent times a hornless bull was the mutant which has given rise to the hornless cattle so frequently seen today. [See Fig. 22–6.]

More mutations have been noted among plants than among animals. Dwarf nasturtiums, dwarf peas, and bush beans are examples. The ostrich fern is one of the mutants of the Boston fern, itself a mutant from a wild tropical fern. The tomato today is the large, fleshy mutant of the much smaller "love apple" which, formerly, no one ate because it was regarded as poisonous. The red sunflower is another plant mutant, which first appeared in Colorado among yellow sunflowers. The seedless orange, or the navel orange, is also a mutant, which appeared first on a single branch of a common orange tree in Brazil. Doubtless a great many mutations have occurred in nature during the past, but only recently have men been on the lookout for such different forms.

More and more, scientists came to the conclusion that the cause of mutations would be found in some sort of alteration of the genes in the reproductive cells. They were right, as subsequent experiments have proved.

Most mutations are recessive characters, so far as heredity is concerned. Also, many mutations are undesirable from the standpoint of the particular organism. For instance, one mutation in the case of fruit flies that occurred in the laboratory was the entire loss of wings. Such wingless mutants outside the laboratory would have perished. [See Fig. 22–7.]

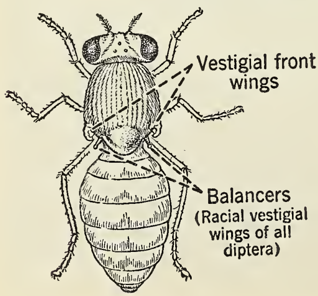



FIG. 22–7. Many mutations that are injurious for the organism occur. If this wingless fruit fly had hatched under nature's conditions instead of in the laboratory, it would have died. Compare this fruit fly with the one in Figure 22–3.

**503. What do modern experiments show as to possible causes of mutations?** In 1927 Professor Muller working in the University of Texas subjected the eggs of fruit flies to the rays from an X-ray machine. The flies hatching from these eggs showed many mutations, in fact from 100 to 200 times as many as in nature. So many similar experiments have been tried with the same results that we accept the conclusion as a scientific fact that X rays can cause actual changes in the offspring.

Ten years later, in 1937, Dr. A. F. Blakeslee, Director of the Carnegie Institution at Cold Spring Harbor, Long Island, began to experiment with a poisonous chemical called *colchicine* (kŏl′chĭ·sēn), which he put on plants and on seeds. Strangely enough, the number of chromosomes in the cells of the parts treated was usually increased, being doubled, tripled, or even quadrupled. Naturally this gave rise to new kinds of plants.

Further experimentation with colchicine has been carried on since 1937 on more than sixty-five kinds of vegetables, flowers, fruits, and trees in the Carnegie Institution and in the Beltsville, Maryland, branch of the United States Department of Agriculture. Some of the practical results already achieved seem miraculous. Larger flowers with new colors, better fruits with strange flavors, sturdier plants with more resistance to disease, and even new and as yet unnamed species have been formed. Colchicine gives standardized results so that a new pure line can be established immediately without the many crossings and years of delay formerly necessary in creating new and stable hybrids. One writer refers to the results of colchicine experimentation as the "most amazing scientific revolution in all history." [See Fig. 22–8.]

From these and other experiments, biologists now think that mutations are produced by (*a*) changes in the structure, number, or arrangement of the chromosomes; (*b*) an alteration of the chemical character of the genes. It is known that high temperatures and increased humidity, as well as the in-

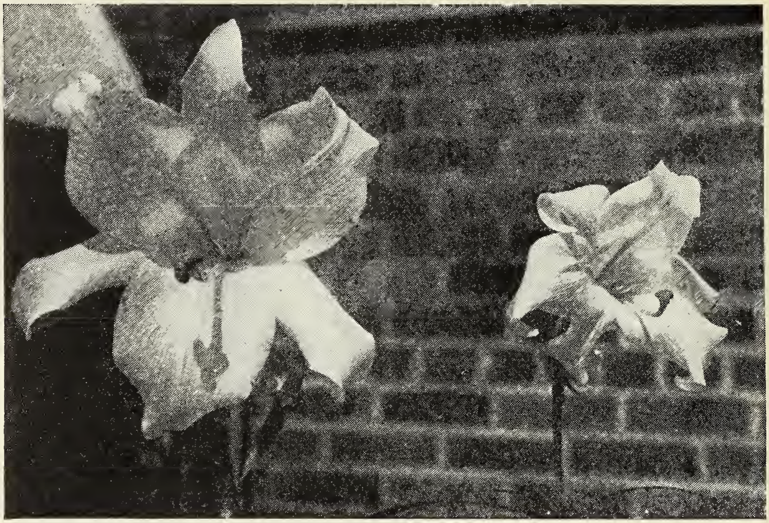


FIG. 22–8. Colchicine solution when placed on plants or seeds produces new and strange alterations. It increases the number of chromosomes, thus giving rise to new species, such as the lily on the left. (*Courtesy Bureau of Industry, United States Department of Agriculture*)

fluence of X rays and colchicine may affect genes and thus produce new kinds of organisms. Undoubtedly other agents and means will be found that can produce mutations.

**504. Twins and multiple offspring.** Usually one egg cell produces one individual organism. In the case of cats, dogs, pigs, rats, and some other animals, several individuals, as you know, are born at about the same time. This litter of baby animals means that not one but several egg cells must have been released and each fertilized by a different sperm cell in the body of the mother animal.

A very interesting case arises when one egg cell after fertilization by one sperm cell divides into two or more cells, each of which becomes an embryo which obviously has the same genetic make-up. Thus we may have what are called *identical twins* — individuals that have come from the same egg cell and the same sperm cell. Such individuals are al-

ways of the same sex, as you should know (see section 495). They also are physical and mental counterparts of each other with amazing likenesses in body and mind. The most notable example of identical human progeny is the Dionne quintuplets where five human organisms have arisen from one single egg cell and a single sperm cell. This instance is unique, and no expense is being spared to derive all the knowledge possible for science from this remarkable brood of children. If each child could be brought up in entirely different surroundings or environments (it would be like *five individuals of the same identity* exposed to different conditions), perhaps the world would have a better answer than any up to the present to that mooted question as to which is more powerful, heredity or environment.

## QUESTIONS

1. Have you seen any fossils of animals? Were they recognizable as ancestors of present-day animals?
2. What are some animals that normally change color at the approach of winter?
3. What ideas formerly prevailed as to the origin of new organisms? Give examples.
4. Have you heard of any superstitious beliefs held by people today concerning the origin of any modern animals?
5. How can we practice the scientific method in order to overcome erroneous beliefs about the origins of living creatures? What are some concrete examples of the use of the scientific method?
6. Can you describe the process of mitosis? In what cells of an organism may it take place?
7. What is the difference between mitosis and maturation? What would eventually happen if maturation did not take place?
8. What have chromosomes to do with the determination of sex?
9. What are the other functions of the chromosomes?
10. What is the difference between a chromosome and a gene?

11. Can you compare the chromosomes and the genes of a muscle cell of a human being, or some other organism, as to numbers? Explain.

12. Why is Gregor Mendel honored today by all biologists?

13. Did Mendel receive any scientific recognition during his lifetime?

14. Who discovered mutations?

15. Can you name a plant mutant and an animal mutant?

16. Are mutations usually dominant or recessive in character?

17. Are most mutations beneficial or detrimental to the organism concerned?

18. How does man utilize the mutations that he finds in organisms?

## *Some things for you to do*

1. Try out some simple crosses with certain flowering plants. To do so, cross-pollinate selected flowers with pollen from other selected flowers, and prevent random pollination by tying paper bags over the flowers you pollinated. By planting indoors in pots, you may be able to get the $F^2$ generation within a year.

2. Try to obtain permission to visit the laboratories of either a college or an experiment station where Mendelian or other breeding experiments are being carried on. If you are successful in making such a visit, write a report on what you observed.

3. Construct large charts of the important tabular representations of Mendelian principles.

4. Make artificial chromosomes of colored plasticine, plaster of Paris, or clay, and place them on chalk drawings on the blackboard to illustrate how chromosomes behave (*a*) during mitosis (*b*) during maturation.

5. If possible, rear different strains of fruit flies and mate them to get new combinations according to the Mendelian laws and possible mutations. (Your teacher will be able to advise you as to the best methods of rearing fruit flies, if such experiments are possible for you to do.)

6. Try Mendelian experiments in the mating of pure white rats and pure hooded or black rats. (Rats are easy to care for, but they must have a continuous supply of water and the right kind of food, and the cage must be kept clean. Learn how to care for these animals before you start.)

7. Try experiments to see what effect colchicine has in producing mutations. (Consult some authority as to procedure and remember that colchicine is a strong poison.)

8. Secure enough information to prepare a table showing your family lines from both parents as far back as you can. Note characteristics of each individual, such as color of eyes, color and type of hair, height, and build, to see what unit characters you can find in your family line.

9. If your school does not have a school experiment plot, try to get permission to have such a garden. If permission is granted, try to arouse enthusiasm for the conducting of Mendelian and horticultural experiments with plants.

## THINK ABOUT THESE!

1. Can you name a new plant or animal developed by man in the last hundred years?
2. Do you know how an animal breeder would proceed to obtain an animal with certain specified characteristics?
3. What is a pedigree and why are such records kept?

## WORDS FOR THIS CHAPTER

**Hybridization.** The producing of crossbreeds by planned matings.
**Pedigree.** The family record of an individual.
**Stock.** As used here, the plant which receives the scion in grafting.
**Scion** (sī′*ŭ*n). The selected twig or bud attached to the stock by grafting.
**Horticulture.** The growing of vegetables, fruits, and ornamental varieties of flowering plants.
**Eugenics** (ū·jĕn′ĭks). The science of improving the human race by application of the laws of heredity.
**Euthenics** (ū·thĕn′ĭks). The science dealing with the improvement of human beings through better environment for living.

*CHAPTER 23* ——————— *UNIT 12*

# *How Can We Use Our Knowledge of Heredity to Improve Living Things?*

**505. What is plant and animal breeding?** Since the period when early man was a wandering nomad, down to modern times, human beings have depended more and more upon the animals they have domesticated, and upon selected wild plants which they have cultivated. Without knowing any scientific rules, they doubtless selected seed from better plants and noted better animals whenever such individuals appeared.

Today plants and animals are bred by modern methods to give the greatest possible value to man for his varied needs. New varieties are constantly being produced, and recognized species are being improved. The following characters are those usually sought after.

*a*) *In flowering plants:* size, color, odor, and number of flowers

FIG. 23–1. This Jersey cow, two and a half years old, has produced 14,137 pounds of milk in one year. (*Courtesy The Borden Co.*)

b) *In garden plants:* size, tenderness, and flavor of edible parts, vigor of plant, early or late ripening, and resistance to disease and drought

c) *In grains:* yield, hardiness, and resistance to disease

d) *In cattle:* quantity of milk, high percentage of cream, value for beef, and in certain regions immunity to Texas fever. [See Fig. 23–1.]

e) *In poultry:* size and number of eggs, and value of this poultry for market, and the resistance of the poultry to disease

Not all the desirable characters can be obtained, as a rule, in any one individual. We do not always know how to obtain a combination of all the desirable qualities to make the perfect organism. Breeders mate two individuals, and by Mendelian methods try to obtain eventually offspring which

retain the better characters of each of the parental lines, and from which at least some of the undesirable traits have been eliminated.

**506. What are the modern methods used by plant and animal breeders?** Plants and animals have been improved and new forms originated, both by *selection* and by *hybridization.* We will first consider selection as this is the oldest method used by man, having been practiced by the ancient Chinese. Selection is practiced by *mass culture* and by *individual culture.*

*a*) Mass culture is used in plant, not animal, breeding, and principally in connection with corn, cotton, and other crop plants. It was one of the favorite methods of Luther Burbank. In mass culture, seed is selected from the most desirable plants of a given kind available, and large quantities of this seed are carefully planted. The cultivated seedlings may give rise to thousands of individual plants from one sowing. Seed from the best individuals of this crop are again planted, and the process is continued until plants with the desired qualities are obtained.

This may take many generations as mass culture is a very slow process. It should be noted that there has been no application of Mendelian principles and, therefore, plants that appear to be larger or to have better flowers or fruits are likely to be hybrids containing recessive genes. In the natural pollination of such a supposedly " improved " variety, the $F^1$ and subsequent generations would be likely to lose some of these qualities, or to degenerate. The process of mass culture may produce some new characters, but some of the " better " individuals may owe their changed appearance to more food, water, or other environmental causes. Such changes would not be hereditary.

*b*) Individual culture has long been common practice in animal breeding. It is now applied to both plants and animals. When this method is employed with plants, seeds from individual specimens that are as nearly perfect as possible are

planted and chance pollination from near-by plants is prevented by covering the flowers or by some other method. Records, or pedigrees, of the offspring of these plants show which plants have the greatest likelihood of continuing the desirable qualities. Desirable mutants, whether among plants or animals, are usually preserved by pedigree culture. Seedless grapes and seedless oranges, " double " flowers that do not make seeds, and various kinds of plants like roses and potatoes, that are not propagated by seeds, are isolated and grown as grafts, or are propagated from stem or bud culture. Individual culture is indicated in cases of especially desirable plants that are self-pollinated, such as oats, wheat, peas, beans, vetch, tobacco.

One of the best examples produced by such individual culture is the *Marquis* wheat. A single plant was found in 1903. The next year there were 12 plants. Six years later there was enough to distribute to 400 farmers. It is now considered to be the most valuable spring wheat in the world. It has full kernels, ripens early, and resists drought. *Kanred* wheat, which is immune to rust disease, has been developed by the Kansas experiment station from wheat originally sent here from Russia. Among animals two types of horses have been developed through thousands of years of careful selection: the spirited and fast horse such as the Arabian steed, and the heavy-muscled work horse of the Percheron type seen in Rosa Bonheur's picture, " The Horse Fair."

**507. What is meant by a pedigree?** Records kept of the family line of exceptionally good horses constitute the *pedigree* of that animal, which when recorded is said to be registered. Such records are kept of many other kinds of high-grade animals such as cows, bulls, dogs, cats, and pigs. [See Fig. 23–2.]

Through pedigree culture, cows have been produced that give either very large quantities of milk (Holstein), milk that is very rich in cream content (Jersey and Guernsey), or that are valuable for beef (Hereford).

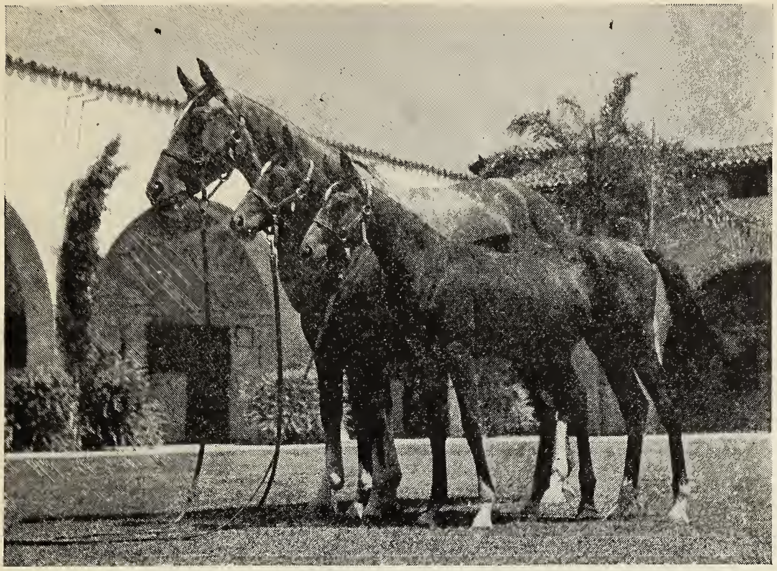


FIG. 23–2. The ears of these three members of the same family show their breeding. What other signs of excellence do you notice? (from FPG)

Animals of good pedigree whose family records have been particularly worthy are usually kept for breeding purposes. Examples of such animals are record-breaking racing horses; cows with a high yield of milk or cream; and pigs, dogs, and cats possessing high rating in points of excellence.

**508. How is hybridization practiced?** For thousands of years man has tried to mate different kinds of organisms. Gradually he has come to realize that the two sexes involved in the mating as a rule must be of the same kind of organism or closely related in form. Pollen from a pumpkin flower would fertilize a squash but not a cherry. Similarly, sperm from a fish would not fertilize frog eggs. However, the jackass has been crossed with a female horse, or mare. The offspring is the mule, which, by the way, usually cannot have offspring. [See Fig. 23–3.] The American bison has been crossed with the cow, and the offspring are known as *cattalo*.

FIG. 23–3. This four-year-old mule was the offspring of a female horse and a jackass. Mules are very valuable in many forms of industry. The traditional stubbornness of mules is outweighed by their strength and their intelligence. (*Courtesy Horse and Mule Association of America*)

**509. What are the advantages of hybridization?** Hybridization is valuable, because *new combinations* are thus made possible. The Mendelian laws are constantly applied, and attention is directed toward the production of a plant or an animal which is *pure* for the desirable qualities. Many hybrids are found to be more vigorous than either of their parents.

For hybridization, cross-pollination is not prevented, but rather encouraged. By this means, characters are segregated and desirable ones noted, and the plants can be selected for pedigree culture.

**510. What are some disadvantages of hybridization?** There are certain disadvantages of hybridization. The large and brilliant flowers of hybrid pansies and hybrid sweet peas, for example, tend year by year to become smaller and lose their bright colors. This happens because the recessive qualities are expressing themselves (segregating) more and more in each successive generation. Hybrids, according to Mendelian laws taken up in the preceding chapter, do not breed

true. The best way to preserve a hybrid plant is to make it reproduce, if possible, by an asexual method, that is, other than by seeds. With certain plants like fruit trees, this is best done by grafting.

**511. How is grafting accomplished?** The plant which receives the graft is called the *stock*. The graft is called the *scion*. The scion may be a root or a twig or a bud. A bud is inserted under the bark of the stock by pushing it under a T-shaped slit made in the bark of the stock. Then raffia is tied tightly around the stock to hold the bud in place until it grows fast. A root or stem scion is cut to fit a corresponding notch or a slit made in the stock. It is then inserted and grafting wax is put around it to keep the air out until the scion and the stock have grown together. The graft is most likely to be successful if the scion is vigorous and if the cambium or growing regions of both stock and scion are brought into union. Grafting is done in the spring. [See Fig. 23–4.]

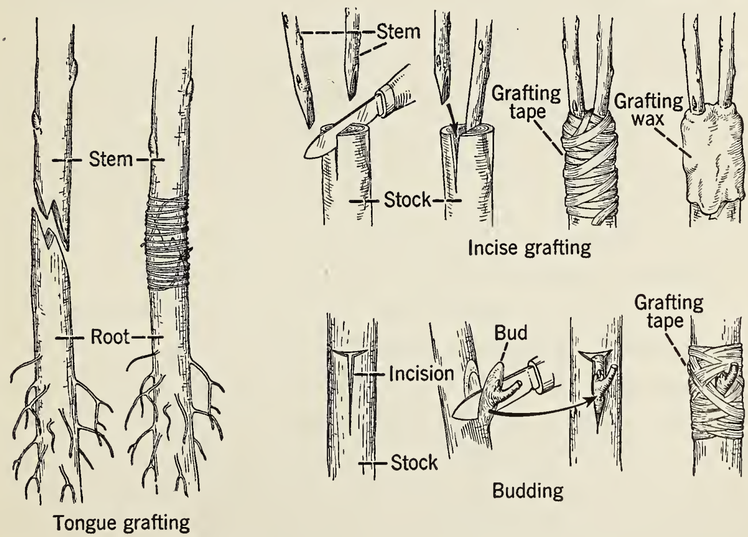



FIG. 23–4. Grafting can give amazing results such as the production of a dozen kinds of fruit on the same tree. Tongue grafting, incise grafting, and budding are shown here.

Grafting gives some amazing results. The fruit of a certain apple tree may not be worth the picking, but the sap which would have produced valueless apples now flows out into the grafts, each of which uses this sap to produce apples of its own kind. An apple tree, if healthy, may thus produce a dozen or more selected kinds of apples. The same thing applies to pears, peaches, plums, grapes, and other stock.

Some other methods of asexual reproduction by which additional hybrid plants may be produced from a parent hybrid are layering; runners; dividing roots, as in dahlia or potatoes; and cuttings. Layering is practiced with gooseberries, raspberries, blackberries, and the like. Ends of twigs are bent over and covered with soil. Roots start, and then connection with the parent plant can be broken. When cuttings are made and planted, new roots will start much more quickly if the lower end of the stem is dusted with a root-growing hormone, such as, " Hormodin " or " Rootone," before being put into wet sand or earth.

**512. What are some examples of valuable plant hybrids?** A Swedish wheat capable of enduring severe cold was crossed with a very productive English squarehead wheat. The plant-breeding station in Sweden thus produced a wheat which would give good crops even in the cold climate of northern regions. Cotton has been improved by crossing Klondike, a good producer, with another species having smooth seeds and long threads. The new plant combines the good qualities of both its parents. Through hybridization, a smut-resistant corn has been produced with an increase of from 200 to 300 per cent in the number of kernels on the ear and a greatly increased number of ears. The large, easily peeled king and temple oranges were obtained by crossing the orange and the tangerine. Our large yellow gladiolus is a hybrid of African and American gladioli. Many new varieties of roses, dahlias, sweet peas, and pansies are the results of hybridization. [See Fig. 23–5.]

Fig. 23–5. Giant pansies, several inches in diameter, and with magnificent colors, are among the hybrid products of modern horticulture. (*Courtesy Ferry-Morse Seed Co.*)

**513. What are some examples of valuable animal hybrids?** Hybridizing and selection have given us more than a dozen types of poultry all developed from the original jungle fowl of India. There are almost as many kinds of doves or pigeons, which have been derived from the rock pigeon of England. The so-called mongrel, or cur, is the hybrid result of random crossing of dogs. Scientific matings and selection with subsequent recrossings have given the world hundreds of breeds of dogs, all of them descendants of an animal probably like the wild wolf, fox, or jackal. Undoubtedly, in the development of so many different breeds or strains of domestic animals, mutations have to some degree played their part.

**514. What is horticulture?** The term *agriculture* is applied to the growing of plants of any kind. *Horticulture* refers to the growing of vegetables, fruits, and ornamental varieties such as flowering plants, shrubs, and trees.

Agriculture undoubtedly had its beginnings in the necessity for food. To that, horticulture adds the culture of plants for the sake of beauty and the protection of man. More than 25,000 kinds of plants are under cultivation in different parts of the world. Mendelian principles and selection are prac-

ticed by farmers and other workers with living things, to provide stock of the finest sort. Having procured the desired seed or the plants, both the amateur gardener and the professional horticulturist face many problems involved in successfully growing and maintaining the resulting plants.

A horticulturist should be acquainted with the principal problems that he will meet in growing new plants. He must know about soils, water, sunlight, plant diseases and enemies — especially insects — as they affect the development of new plants.

**515. What problems must a horticulturist face in growing new plants?** (*a*) First, the soil must be considered. For most plants it must not be heavy with clay, or very sandy. A dark loam is considered best. Plants like blueberries, cranberries, some ferns, mountain laurel, rhododendron, and trailing arbutus, require an acid soil. The majority of plants could not live in an acid soil. All plants, however, must be provided with mineral matter from which they can make nutrients. Such mineral matter can be put into impoverished soil by addition of manures or commercial fertilizers. Maintaining the fertility of the soil is an essential.

*b*) The amount of water required by different plants is also an important item. Many plants such as the cactus, yucca, agave, live-for-ever, and even beans actually grow well under more or less arid conditions. Water lilies, cattails, lotus, iris, and some ferns thrive in water itself or in moist places. Most other plants require a more or less moderate but regular supply of water for successful existence. Frequent stirring of the ground, which is one of the principles of "dry farming," helps greatly to retain moisture in the ground. Hoeing or raking breaks up soil particles which, if packed together, would otherwise act like a wick through which moisture in the soil could come to the surface and evaporate into the air.

In recent years a new method of growing plants in water, without any soil, has become very popular. This kind of

plant culture is called hydroponics, from the Greek word *hydor* meaning *water,* and *ponos* meaning *labor.* The plants are supported on racks with their roots immersed in the water to which chemicals that would be found in normally rich soil have been added. More than ordinarily abundant crops of tomatoes, potatoes, beans, spinach, melons, and many other plants have been obtained by this method, in places where no soil is available.

*c*) The amount of sunlight is a factor. Ferns, wildflowers, rhododendrons, laurel, and lily of the valley develop best in shaded places. The vegetable plants, especially corn, and practically all plants cultivated for their flowers, flourish in sunlight, provided they have sufficient water.

*d*) The grower of plants should be well informed about the structure and functions of a typical plant, in order to appreciate the problems of plant physiology. He should know about root hairs and the importance of keeping some of the original earth around the roots when transplanting. Wilting through excessive transpiration must not be confused with wilting from root damage by cutworms or other insects. He should know why pruning is important and why the girdling of a tree by mice or rabbits may kill it. He should understand why a "bridge graft" can save a girdled tree. He should also understand the importance of other types of grafting. He ought to know that earthworms are very beneficial to plants because they constantly increase the fertility of the soil.

*e*) Plant diseases also have to be studied. Their avoidance is easier than their cure. The use of fungicides and sprays is indicated in many cases. The Department of Agriculture will supply literature on this subject if asked to do so.

*f*) There is also the continuous problem of competition from undesirable plants known as weeds. There must be no let-up in this warfare throughout the growing season. Weeds, with their rapid growth, not only compete for space, but they extract valuable mineral substances from the soil.

In spite of these and other enemies, such as moles, field mice, slugs, and a few birds like the yellow-bellied sapsucker, the English sparrow, together with blackbirds and robins at certain seasons, a person who is willing to be fairly industrious and thoughtful, and who knows and uses scientific methods, can have a successful orchard, or a garden of vegetables, flowers, or small fruits. However, the matter of insect control is so very important that this topic must be considered separately.

**516. What can the horticulturist do to control harmful insects?** There are a large number of insects that are beneficial to man. But there are so many destructive species that constant vigilance is necessary. New plants may not be hardy enough to withstand damage from the insects. Well-established plants have to be equally protected. Obnoxious insects cost the country at large over $2,000,000,000, annually, of which every careless gardener pays his full share.

There are three constructive measures in horticulture, all of which are important.

*a*) Encourage wild birds, toads, and harmless snakes. They all eat quantities of harmful insects and do " overtime work " for us without pay.

*b*) When corn becomes infested with the corn-borer or cotton becomes infested with the cotton-boll weevil, practice rotation of crops by growing other plants in the infected area for a season or two.

*c*) Use reliable insecticides in liquid or powder form. Paris green, arsenate of lead, and Bordeaux mixture can be sprayed or sprinkled on plants so that insects will then have to eat poisoned leaves. Hellebore and insect powder kill worms on currants and some other plants. Sucking insects like scales and plant lice may be controlled by contact poisons such as nicotine solution, whale-oil soap emulsion, and sulfur-lime wash. Write to seed firms or to the Bureau of Entomology, Washington, D. C., for directions for making and using insecticides. [See Fig. 23–6.]

FIG. 23–6. Insect enemies of trees can be controlled or eradicated by spraying the leaves with poisons such as arsenate of lead. In the country, signs are usually put up to warn against letting cattle graze on the grass under trees that have been sprayed. (*Courtesy The Davey Tree Expert Co.*)

There are over a hundred kinds of insects that are injurious to our cultivated plants. Persons who are most successful in combating insects have taken the time to find out the habits and life histories of these six-footed pests, and have studied the best ways to meet the problem.

***517. To what extent can animal breeding be practiced?** Pedigreed horses and cattle may command prices running into thousands of dollars. This alone prevents any but persons who are well-to-do from breeding such animals. However, pure-line dogs, with registered pedigrees, can be bought for relatively small amounts. A great many persons have such animals. The sale of puppies from planned matings may be quite lucrative. The scientific aspects of animal breeding, whether the animals used as parents are selected

doves, poultry, guinea pigs, white rats, dogs, cats, or even tropical fishes, appeal to many persons.

The length of time between fertilization and birth in cats is 65 days; in dogs, 63 days; in rats, 28 days; and in guinea pigs, 21 days. It is quite possible to conduct breeding experiments along Mendelian lines with rats and guinea pigs and get results comparatively soon. Animals that are of pure stock have a recognized value, although pure-blooded or pedigreed animals are not necessarily more affectionate or valuable in other ways than animals that are somewhat hybrid.

**518. Are all living things of any one kind alike?** One hundred seeds of the same kind will rarely produce one hundred plants. Seeds vary in vigor. The seedlings that do develop into organisms will not be all of the same size. Some will be strong; some will be weak; a few may be puny. In a pack of wild horses, one is the leader, because of greater strength, speed, and cunning. Plants and animals always vary in many physical characteristics among their own kind. In addition, mutations bring about even greater differences.

**519. Are all persons biologically equal?** The opening words of the Preamble of the Constitution of the United States proclaim that "All men are created free and *equal.*" That inspiring sentence emphasizes the equality of every citizen of the United States in the eyes of the law. This is true. But, biologically speaking, individual persons vary in their mental qualities and in their physical qualities, as do plants and animals. The Selective Service Act of 1940 has revealed the great differences in physical characteristics in men who outwardly resemble one another. Mentally, too, there are great differences between one human being and another. Studies conducted over a period of twenty-five years show that there are varying degrees of human intelligence, from the idiot, imbecile, and moron (all feebleminded), to the subnormal, then up to the normal, the superior, and finally to the genius.

**520. Are there good family lines?** Many family lines have been studied thoroughly. Investigations show that a special ability, for example, often runs in many of the members of one family. Thus the Herreshoff family has long been noted for boatbuilding accomplishments. Many of the cup-winning yachts have been designed and built by them. The majority of that family are especially gifted mechanically.

In the realm of music, almost every musician who might be called a master has many relatives in his family line possessing marked musical ability. The Bach family line is an example. We all know of the musical genius of Johann Sebastian Bach. But it is not so well known that in six generations of his family there were 47 artists of quality, of whom 29 became noted musicians. [See Fig. 23–8.] Records show many other family lines whose members have made similar contributions to the world.

**521. Who were the Kallikaks and the Jukeses?** We have been considering human heredity of the better kind. In contrast to this good stock are family lines in which the worst sort of humanity is predominant. Perhaps the most striking example of such degenerate, or bad, heritage is the Kallikak family. That family line began about the time of the Revolutionary War. There were 480 descendants in 1912. Of this number 252 were unknown, 82 died in infancy, 24 were alcoholics, 41 were degenerate, and 143 were feeble-minded. Only 46 were normal enough to go to school, and not one of these could be considered superior.

The Jukes family consisted of over 1000 descendants of a ne'er-do-well backwoodsman who settled in western New York in the early days of its history. The majority were feeble-minded, and 130 were criminals. *Not a single individual had even an elementary-school education.* Up to 1877 this family had cost the State of New York more than $1,250,000. No one seems to have dared to estimate the amount since that time. We, as taxpayers, pay such bills. What can we do about it?

**522. What is eugenics?** In the last 75 or 100 years, advances have been made in many directions aimed at human improvement. The world owes much to an English scientist, Sir Francis Galton. About the time of our War between the States, he saw that most of the efforts made to improve human stock, such as better education, improved housing, general hospitalization, and sounder economic conditions, were only environmental. He realized that better living conditions produce happier, healthier, and undoubtedly longer-lived individuals. But very little of this improvement passes on to the next generation. Every baby has to start out anew with whatever heredity has been given to it and climb its own ladder of life. It was evident to Galton that environmental improvement could do little to improve *future* generations. No horticulturist can change a crab apple into a McIntosh apple, although by careful fertilizing, watering, pruning, and other environmental care he can obtain bigger and better crab apples. In the same way, if a child is given a better environment than his parents had, he will in all probability grow up to be a better specimen, physically and mentally, than his parents. But he will still inherit his parents' characteristics. A child born of a mechanically minded family is very likely to be mechanically minded himself, while a child born into a musical family will generally grow up to be musical.

Galton felt so keenly about this that he lectured and wrote on the subject of human improvement, for which he coined the word eugenics from the two Greek words: *eu* meaning "well" and *genos* meaning "race." He defined eugenics as "the study of agencies under social control that may improve or impair the racial qualities of future generations either physically or mentally." It might be shortened to the phrase "improvement of human heredity."

**523. To what extent is eugenics being used today?** Constantly increasing numbers of citizens are realizing the principles of heredity upon which eugenics is based, through

Fig. 23–7. In the family line of Johann Sebastian Bach, genes for musical ability seemed to determine individual talents. In six generations there were forty-seven noted musicians. (*Culver Service*)

information given by biological courses in schools and colleges. In the light of this knowledge, public opinion has brought about the passing of several constructive laws. Diseased immigrants cannot enter this country. Many states now require a certificate of good health from those who are about to be married. Other measures are being considered. Undoubtedly the civilized world today knows more biological truth than it is willing to practice. But there is constant, if slow, progress in the improvement of human stock by the lessening of disease, crime, and property, and by the development of higher standards of human living.

**524. How much can man really improve himself?** Earlier in this chapter we discussed ways and means of improving plants and animals. How much, if any, of this knowledge is applied, or should be applied, to the improvement of man himself? The answer is that certain mental and physical traits are present at birth, inherited from parents, grand-

parents, and others of the family lines. But proper physical training can improve our bodies. In the same way, education can develop our minds. In a democracy, such as the United States, each individual has a right to all the training and education that are needed to develop his personality and capacity to the fullest.

525. What is the goal for each individual? There are many kinds of work to be done in the world and there must be a variety of kinds of individuals to meet these different needs. We need heavy draft horses as well as fast racers; beef cattle as well as good dairy cows; crab apples as well as McIntosh apples. So, among humans, great leaders gather devoted followers, worth-while musicians play to keen listeners, good athletes are applauded by enthusiastic sports fans, and conscientious teachers have co-operative pupils. Each needs the other. Different persons are differently endowed, but almost every individual is born with the capacity to live a useful and happy life. It is of the greatest importance that the talents of each person be discovered early in life and be widely developed so that his abilities and skills may be utilized for his personal satisfaction and for usefulness to others.

In plant and animal breeding we found that scientific selection, based on the laws of heredity, gave us better organisms. These organisms were then given the best sort of environment for fullest development. Even though we cannot expect to apply selection to human beings as we do with plants and animals, eugenics can be of the greatest help in the avoidance of much misery, sorrow, and needless expense. If to this is added the environmental training of education, sometimes called *euthenics* (from the Greek word *euthenia,* meaning " well-being ") human living will continue to progress to new heights of achievements. Perhaps this is the greatest aim that a democracy can have for its citizens. Each boy and girl has a share in making it possible.

## *Questions*

1. What are the methods of plant and animal breeders?
2. What are the characters sought by breeders in new organisms?
3. What is meant by a pedigree?
4. Can you give examples of plants improved by mass culture?
5. What is individual selection? What results has it given the world?
6. Why is hybridization the most scientific method of breeding?
7. Can you name several desirable plant hybrids and several desirable animal hybrids?
8. Is it possible that a hybrid might be more desirable than pure-line organisms? Less desirable? Explain.
9. How is grafting done?
10. What is accomplished by grafting?
11. What problems must the gardener and the horticulturist solve in order to grow successful plants, flowers, and fruits?
12. Name some of the worst insect pests. What treatment is recommended for each?
13. What plants require an acid soil?
14. Who was the father of the science of eugenics?
15. What do you think has more influence upon the development of an individual, heredity or environment?
16. What do you think could be done to reduce crime, poverty, insanity and feeble-mindedness?
17. Why is it important to ascertain one's talents early in life?
18. Which do you regard as the more important in possible good effects: eugenics or euthenics?

## *Some things for you to do*

1. Read about the development of the Red Fife wheat of Canada or the Biffen wheat of England. Then write a report on one or both of these valuable strains, each of which is an example of modern breeding methods.

2. Visit the gardens and greenhouses of some seed firm to observe their methods. Write a report on your visit.

3. Get a copy of the pedigree of some prize animal such as a horse or a cow, with the records of each individual mentioned.

4. Procure seeds of new hybrid strains of sweet peas, pansies, or other flowering plants. See how the strain deteriorates in size and color from generation to generation. (Perhaps one of your friends who raises flowers will collaborate with you on this experiment.)

5. Write to the Carnegie Institution, Cold Springs Harbor, New York, for record blanks and other eugenics literature.

6. Organize a discussion in your class on the subject: "Is heredity or environment more powerful in making an individual what he or she is?"

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# Glossary

Abdomen (ăb·dō′mĕn), in mammals, the region of the trunk below or posterior to the diaphragm; in insects, the hinder part of the body.

Adulteration, rendering a substance impure, or dangerous to the consumer, through the substitution of inferior substances, the omission of important ingredients, or the addition of injurious substances.

Aerobic (ā′ẽr·ō′bĭk), bacteria that require free oxygen in contrast to other bacteria that can live without free oxygen.

Agar (ä′gär), a substance extracted from seaweed; it resembles gelatin.

Agriculture, the term applied to the growing of plants of any kind.

Albino (ăl·bī′nō), an animal, rarely a plant, that is white due to the absence of pigment.

Albumen (ăl·bū′mĕn), a protein found in the white of egg.

Algae, flowerless plants, including most seaweeds and many kinds of fresh-water plants.

Alloy, a substance which contains a uniform mixture of two or more metals, usually formed by melting the two metals together.

Alternating current, an electrical current which flows for a fraction of a second in one direction, and then for an equal fraction flows in the other direction.

Ammeter, an instrument used to measure units of current strength, or amperes.

Amperage (ăm·pẽr′ĭj), the amount of current flowing in a circuit.

Ampere, the unit used to measure the strength of an electrical current.

Amplify, of a sound, to increase; to augment; to intensify.

Anaerobic (ăn·ā′ẽr·ō′bĭk), able to live without free oxygen.

Anode, the positive terminal of a secondary or electrolytic cell.

Antennae, of a radio, the aerial wires.

Anther, the upper part of a stamen in which pollen is developed.

Anthrax, an infectious and usually fatal disease of animals.

Antibodies, various substances found in the blood, which cells have manufactured as a means of combating disease germs.

Apogee (ăp′ô·jē), the point farthest distant from the earth in the orbit of a heavenly body.

Appendix, a narrow blind pouch, 3 to 4 inches long, attached to the tip of the large intestine, in man and a few other animals.

Armature (är′mȧ·tūr), that part of a dynamo whose coils cut the lines of force of the field magnet.

Asphalt, a solid substance found naturally and obtained as a residue from certain petroleums and coal tar. It is widely used for paving and roofing.

Asteroid, a small planet.

Audion, a vacuum tube used for many purposes in radio work.

Axis, an imaginary straight line passing through a body, on which that body supposedly rotates.

Babesia, a parasite causing Texas fever, a disease of cattle in the southern part of the United States.

Bacillus (bȧ·sĭl′ŭs), plural Bacilli (bȧ·sĭl′ī), any individual of a large group of rod-shaped bacteria.

Bacteriology, the science dealing with the study of bacteria.

Bacterium, plural Bacteria, a single cell of certain one-celled flowerless plants.

Beriberi, a deficiency disease due to the lack of vitamin $B_1$.

Bile, a yellowish liquid produced in the liver and passed off into the intestine from the gall bladder. It aids in digestion.

Blade, the broad, usually thin and expanded portion of a leaf.

Burning, oxidation which takes place so rapidly that both heat and light are produced.

Calyx, the outer series of floral leaves, each called a sepal; usually green in color.

Cam, a device used to change rotary motion into to-and-fro motion.

Candle power, the quantity of light given out by a standard candle.

Carbohydrate, any one of several groups of compounds containing carbon, hydrogen, and oxygen. Carbohydrates are one of the major nutrients in man's food.

Carbonize, to heat until charred.

Carburetor, a device which is used to mix air and gasoline, or other vapor, to form an explosive mixture.

Casein (kā′sē·ĭn), a protein substance found in milk.

Catalyst (kăt′ȧ·lĭst), a chemical substance which changes the structure or character of other substances without itself being changed.

Cathode, the plate, or electrode, which is attached to the negative terminal of the dry cells or the dynamo, used with an electrolytic cell.

Centrifugal (sĕn·trĭf′ū·găl) force, a force pulling from the center.

Chromatin (krō′mȧ·tĭn), the hereditary material found in the nucleus of a cell before being organized into chromosomes.

Chromosome, one of the divisions of the chromatin in the nucleus of a cell, concerned with the heredity of the animal or plant to which it belongs.

Coccus (kŏk′ŭs), plural Cocci (kŏk′sī), any one individual of a group of ball-shaped bacteria.

Coherer, a wave detector devised by Marconi.

Comet, a luminous heavenly body, which follows an orbit around the sun. It frequently has a long tail.

Commutator, a device which changes an alternating electric current into direct current.

Complete flower, a flower having all the four floral parts, sepals, petals, stamens, and pistil.

Condensations, referring to sound, those parts of a sound wave in which the air is compressed.

Conduit, a pipe used to conduct liquids.

Constellation, of stars, a group of fixed stars. There are about 90 such groups now recognized by astronomers.

Copper, a common metal found native and in various ores; one of the best conductors of heat and electricity.

Corolla, the petals of a flower, taken collectively.

Cortex, part of the bark; the spongy layer underneath the epidermis of roots.

Cosmic ray, a ray of exceedingly short wave length. These rays may come from outer space or from disintegrating matter.

Creosote, a chemical obtained from coal tar. It preserves wood.

Cultures, planned growths of organisms on food material or in a favorable environment.

Cured, the preservation of pork or other meat by saturating it with smoke. Pork then becomes ham or bacon.

Decay, rotting; the process of breaking down organic substances by bacteria.

Declination, the deviation of a magnetic needle from the true north.

Deficiency disease, a disease caused by lack of a certain vitamin.

Desiccated (dĕs′ĭ·kāt′ĕd), dried.

Diagnosis, the recognition of a disease by certain symptoms.

Diastase (dī′ȧ·stās), a digestive enzyme found in both plants and animals; it alters starch and sugar.

Diatom, any one individual of a certain family of aquatic microscopic Algae.

Differential, a device in the rear axle of an automobile. It permits one wheel to turn faster than the opposite one.

Diffusion, the intermingling of the molecules of two fluids in contact or separated by a membrane. Diffusion through a membrane is commonly called osmosis.

Direct current, electrical current which flows in only one direction.

Displacement, the weight of water displaced by a ship or vessel in floating.

Dominant, a character that appears to exclude its opposite, which is a recessive character.

Dúmet, an alloy of the metals nickel and iron, which expands at the same rate as glass. It is used in the place of the more expensive platinum for the "lead-in" wires of bulbs.

Dynamo, a machine used to generate electricity; a generator with a commutator.

Efficiency, the useful work done by a machine compared to the total work put into the machine.

Effort, force; usually referring to a force applied to a machine.

Electrolysis (ė·lĕk'trŏl'ĭ·sĭs), the breaking up of a compound by the use of the electric current.

Electrolyte (ė·lĕk'trȯ·līt), the solution in a cell in which electrolysis takes place.

Electromagnet, a device which has magnetic properties when a current flows through its coils.

Electron, a negatively charged particle of matter.

Electroscope, an instrument used to detect the presence of an electric charge.

Electrotype, a plate used principally in printing, and made by taking an impression of the type in wax or soft lead. This impression is filled by electrolysis with a thin shell of copper or other metal and backed with molten metal.

Ellipse, a closed curve like a lengthened, or elongated, circle.

Elodea (ė·lō'dė·ȧ), a family of small aquatic plants, also known as Anacharis.

Energy, the capacity to do work.

Entrails (ĕn'trālz), the internal organs of an animal, especially the intestines.

Equator, an imaginary circle around the earth's surface, equidistant at all points from the poles. It divides the earth into the northern and southern hemisphere.

Equilateral, having sides of equal length.

Equinox, two periods in the course of the year, in spring and in fall, when the sun's center crosses the equator and day and night are everywhere of about equal length.

Equivalent, of equal value; capable of producing the same effect.

Ether, an imaginary, weightless fluid through which heat, light, and radio waves are transmitted; an anaesthetic gas.

Eugenics (ů·jĕn′ĭks), the science of improving the human race by application of the laws of heredity.

Euglena, a microscopic animal which has chlorophyll and can manufacture food as a green plant does.

Euthenics (ů·thĕn′ĭks), the science dealing with the improvement of the human race through better environmental conditions for living.

Filterable virus, a disease-producing organism or its products, so small as to pass through laboratory filters.

Fixed animal, one with no means of locomotion, such as the adult sponge, sea anemone, and oyster.

Fixed star, one whose position with relation to other stars remains constant for periods of time.

Flagellum (flȧ·jĕl′ŭm), a small hairlike extension larger than a cilium, found on certain bacteria and on certain protozoan animals.

Flashing, strips of metal used to make watertight joints between a wall and a roof surface or between two intersecting roof surfaces.

Flotation, pertaining to floating objects.

Fluoroscope, an instrument used by doctors and others to see the shadows cast by objects in the path of X rays.

Foot-candle, the amount of light an object receives at a distance of one foot from a light source of one candle power.

Footings, broad foundations upon which the walls of a house are built.

Formaldehyde, a colorless gas with a strong odor, usually dissolved in water for use as a disinfectant and for other purposes.

Friction, the resistance which, when in contact, opposes any force trying to produce motion.

Fulcrum, the fixed support about which a lever moves.

Fungicide (fŭn′jĭ·sīd), an agent or substance capable of killing fungi.

Furring, wooden strips to which lath or other material is fastened.

Fuselage (fū′zĕ·lĭj), of an airplane, the streamlined portion of the plane which carries the passenger, the cargo, and possibly the power plant.

Fusible, capable of being melted or liquefied.

Galaxy (găl′ă̆k·sĭ), a great cluster of stars, the Milky Way, for example.

Galvanometer, an instrument for measuring or detecting an electric current.

Gas, a fluid substance having neither shape nor definite size.

Gaseous, pertaining to matter in the form of a gas.

Gasoline gauge, an instrument on the instrument panel of an automobile that shows the amount of gasoline in the fuel tank.

Gene (jēn), a part or region of a chromosome believed to be the physical basis for one of the hereditary characteristics of the offspring.

Genetic (jė̇·nĕt′ĭk), relating to heredity.

Gibbous (gĭb′ŭs), swelling out.

Graphite (grăf′īt), a soft element consisting of carbon; it is used in the making of electrotypes, and also for lead pencils.

Gravitation, that force which attracts two bodies to each other.

Guard cell, one of the two epidermal cells surrounding a stoma.

Heat, a form of energy believed due to molecular motion.

Helix, a spiral coil of wire.

Heredity, the likeness of offspring to their parents or to their family line.

Horsepower, rate of doing work. One horsepower is the amount of work done in raising 550 pounds one foot per second.

Horticulture, the term applied to the growing of vegetables, fruits, and ornamental varieties such as flowering plants, shrubs, and trees.

Hydrometer (hī·drŏm′ė̇·tĕr), an instrument for determining the specific gravity of liquids, or for testing batteries.

Hydrophobia, a disease produced by virus transmitted from the saliva of a "mad" dog or other animal suffering from rabies.

Hypothesis, a scientific guess; some belief that cannot yet be proved.

Iconoscope, the transmitting tube used in television.

Illuminated, shining because it reflects part of the light that falls upon it.

Impulse, nerve activity set up by a stimulus.

Incomplete flower, a flower that lacks one or more of the four main floral parts.

Inertia, that property of matter which tends to keep an object in motion if it is in motion, and to keep it at rest when it is at rest.

Infection, establishment in an organism of bacteria which have locally overcome the body's defenses against disease.

Instantaneous, requiring only an instant.

Iris, in the eye, a muscular, colored curtain surrounding the pupil.

Irradiation, exposure to radiations of light or other rays.

Kelp, any of the large brown seaweeds.

Kilocycles, one thousand cycles.

Latitude, angular distance from a circle of reference; angular distance north or south of the equator, measured along the meridians.

Lead, a metallic element found as a constituent in ores and other minerals.

Lenticel (lĕn′tĭ·sĕl), one of the openings found in the outer bark of most plants.

Lightning arrestor, a device for protecting electrical apparatus against lightning.

Light-year, a term used by astronomers as a measure of distance. It equals the distance which light will travel in one year.

Limestone, a sedimentary rock, composed of deposits of calcium carbonate.

Linoxyn (lĭ·nŏk′sĭn), the name given to the leathery skin formed when oxygen unites with linseed oil.

Lodestone, a natural magnet.

Longitude, angular distance east or west of an imaginary line on the earth's surface.

Luminous, shining from its own light.

Lunar month, the period of time that elapses between one new moon and the next, or a complete revolution of the moon.

Lysin (lī′sĭn), a protective substance, produced normally in the blood; it dissolves bacteria.

Magnetic material, any substance which is attracted by a magnet.

Magnetism, the property of certain substances, such as iron, which enables them to be magnetized, or attracted, to another substance acting as a magnet.

Magnetite (măg′nĕ·tīt), a magnetic iron ore found in nature.

Magnitude, referring to the brightness of stars. First-magnitude stars are very bright.

Mantoux test, a test given to diagnose tuberculosis.

Meridian, the highest point reached by a heavenly body in its course; a true north-and-south line; an imaginary line extending from pole to pole.

Meteor, a heavenly body that passes through the earth's atmosphere at high speed.

METEORITE, a meteor that falls upon the earth's surface.
MICROBE, a microscopic organism, especially bacteria.
MICROORGANISM, a microscopic organism, such as a microbe.
MILDEW, a form of fungus.
MILKY WAY, a galaxy of stars.
MINERAL MATTER, inorganic substances found in nature.
MITOSIS (mĭ·tō′sĭs), the changes primarily associated with chromosomes, in the nucleus, that take place within a cell at the time of cell division.
MNEMONICS (nē̇·mŏn′ĭks), a means of improving the memory by the association of sets of figures or objects.
MODIFY, to change or acquire new characteristics.
MOON, the satellite of the earth. The name is also used for the satellites of the other planets.
MOSAIC DISEASE, a disease of plants in which the leaves become spotted or mottled, due to infection with a virus.
MULLIONED, having divisions formed by slender bars or pillars.

NEAP (nēp), a tide produced when the moon is at first or at third quarter.
NEBULA (nĕb′ū̇·lȧ), plural NEBULAE (nĕb′ū̇·lē), a cloudlike mass of stars.
NETTED-VEINED, an arrangement of veins in a leaf in which the small veins form a network, as contrasted with parallel veining.
NICHROME (nī′krōm), an alloy which has a high melting point and offers considerable resistance to the electric current.
NODE, of the moon, one of the two points in its orbit where it intersects the plane of the earth's orbit.
NORTH POLE, the farthest point north from the equator; the northern end of the earth's axis.
NOSEMA, a parasite causing pebrine, a disease which attacks silkworms.
NOVA, a new star, or one that temporarily increases its light and energy output.

OHM, the unit used to measure electrical resistance.
OPAQUE (ō̇·pāk′), not permitting light to shine through.
OPEN CIRCUIT, in electricity, a circuit in which there is a break or gap in the connection at some point across which no current can flow.
OPSONIN (ŏp′sō̇·nĭn), a protective substance, normally produced in the blood, which alters invading bacteria so that they can easily be destroyed.
ORBIT, the path followed by a heavenly body around another body.

PALISADE CELL, one of the long green cells that together form the portion of the leaf found in the upper region below the epidermis.

PALMATE-NETTED VEINING, having several veins extending through the blade from the petiole, somewhat like fingers.

PARALLEL-VEINED, an arrangement of veins in a leaf in which the small veins run parallel, as contrasted with netted veining.

PATHOGENIC (păth′ō̇·jĕn′ĭk), capable of causing disease.

PEBRINE, a disease which attacks silkworms.

PEDIGREE, the record of the family line of an individual.

PELLAGRA (pĕ·lā′grȧ), a deficiency disease due to lack of vitamin P-P.

PENUMBRA (pē̇·nŭm′brȧ), a partial shadow; a place from which part of the light has been cut out.

PERIGEE (pĕr′ĭ·jē), the point nearest the earth in the orbit of the moon.

PERIOD, of a planet, the amount of time it takes to revolve around the sun.

PERISCOPE, a device which permits persons under water, in a submarine, for example, to see objects above the surface of the water.

PERMANENT MAGNET, a magnet made of hard steel, or alloys of nickel and cobalt.

PERSPECTIVE, depth of vision.

PETIOLE (pĕt′ĭ·ōl), the stem of a leaf.

PHENOMENON (fē̇·nŏm′ē̇·nŏn), an observable fact or event.

PHLEGM (flĕm), mucus secreted in the lungs, throat, or nasal passages.

PHOSPHATASE (fŏs′fȧ·tās) FIELD TEST, a test made by milk inspectors to check the thoroughness of the pasteurization of milk and cream.

PHOTOSYNTHESIS (fō′tō̇·sĭn′thē̇·sĭs), the process of carbohydrate formation in leaves; uniting carbon dioxide and water by means of chlorophyll in the presence of light.

PINNATE-NETTED VEINING, featherlike veining in leaves.

PISTILLATE (pĭs′tĭ·lȧt), an incomplete and imperfect flower, possessing a pistil but no stamens.

PLANETOID, a heavenly body resembling a planet; an asteroid.

PLANKTON, the floating or drifting life of the sea and of fresh water, consisting mostly of minute plants and animals.

PLASTID, one of the tiny, rounded grains found in certain plant cells and containing the chlorophyll.

POLARITY, a state of having poles, or places at which magnetic force is concentrated.

POLE, either end of the axis of any heavenly body.

POLLINATION, the transference of pollen from the stamens to the top of the pistil.

POTABLE, pure enough to drink.

Power, as used by scientists, the rate of doing work.

Prime meridian, an imaginary line drawn through the equator, from pole to pole, and passing through Greenwich, England.

Proton, the part of an atom which carries a positive charge of electricity.

Protozoa, the lowest, or one-celled, animals.

Psyche (sī′kė), the mind or human soul.

Psychology (sī·kŏl′ȯ·jĭ), the science dealing with the study of the mind.

Radio wave, an electric wave having radio frequency.

Radium, an element discovered by Madame Curie.

Rarefied, made less dense.

Rarefy, to decrease in density.

Ray, a single outer floret of a composite flower.

Recessive, a character that is apparently overshadowed and suppressed by its opposite and dominant character.

Rectifier, a device which changes alternating current into direct current.

Refraction, the bending of a ray of light as it passes from one medium into another one of different density.

Repel, to force apart.

Resin, a secretion from pines and some other trees, used in making varnishes and medicines, and in other ways.

Resistance, opposed to motion; opposition.

Revolve, to travel in a path around some object.

Rickets, a deficiency disease due to the lack of vitamin D.

Rock wool, a substance made from molten rock or slag. It is fibrous and woollike, and is used for heat and sound insulation.

Root hair, one of the delicate one-celled extensions from a growing root.

Root stock, an underground stem.

Rotate, to turn on its axis.

Rotor (rō′tẽr), the rotating part of a turbine or generator.

Rust, a group of parasitic fungi; the oxide produced when iron combines with oxygen.

Saprophyte (săp′rȯ·fīt), an organism that feeds only upon dead organic matter.

Satellite, a heavenly body revolving around another, larger one.

Schick test, a test devised in 1913 by Dr. Schick to determine the susceptibility of a child to diphtheria.

Scion (sī′ŭn), the selected twig or bud attached to the stock by grafting.

Scrim, a light, coarse, cotton fabric.

Self-pollination, the transference of pollen from the anther to the stigma of the same flower.

Sensation, a feeling which is caused by some stimulus.

Sepal (sē′păl), one of the leaflike parts of the calyx.

Series grouping, a cell grouping in which the positive of one cell is connected to the negative of an adjoining cell.

Shellac, a varnish obtained from the secretions of the lac insect.

Short circuit, a circuit through a small resistance which acts as a shunt to a circuit of larger resistance.

Shunt, one of the branches of a divided electric circuit.

Silica, an extremely hard, white or colorless substance. The oxide of silicon, found pure as quartz, opal, sand, also occurs in some organisms as sponges and diatoms.

Skull, the cranium or head bones of a vertebrate animal.

Slate, a fine-grained rock which was once clay or shale, but has since become metamorphized, or changed by heat and pressure in the earth.

Smut, a parasitic plant.

Sodium, a silver-white element present in common table salt.

Sodium hydroxide, a corrosive compound which is used for cleaning greasy sinks and for making soap.

Solar system, the sun and the group of heavenly bodies revolving around the sun.

Solstice, one of the two periods in the year when the direct rays of the sun are farthest from the equator.

South Pole, the farthest point south from the equator; the southern end of the earth's axis.

Spectroscope, an instrument used to produce and to study spectra.

Spectrum, plural Spectra, a band of colors formed by separating the colors in compound light.

Spirillum (spī·rĭl′ŭm), plural Spirilla (spī·rĭl′ȧ), one individual of a large group of spiral-shaped bacteria.

Spirogyra (spī′rô·jī′rȧ), a large family of green fresh-water Algae.

Spleen, the abdominal organs in many vertebrates, in which old red blood cells are destroyed.

Spore, a minute reproductive body, usually a cell, by means of which certain flowerless plants, such as bacteria, molds, and some protozoan animals, reproduce.

Sputum (spū′tŭm), saliva or expectorated matter.

STAMEN, a threadlike part of a flower on the top of which pollen is formed.

STAMINATE (stăm′ĭ·nåt), an imperfect flower, possessing stamens but no pistil.

STAR, a heavenly body which is hot enough to shine of its own light.

STATIC, referring to an electric charge at rest.

STATIC ELECTRICITY, that type of electricity generated upon an insulator. Hence the electrical charge does not flow, but remains at rest.

STATOR (stā′tẽr), the stationary part of a turbine or generator.

STIGMA, the upper extremity of the pistil which receives pollen in pollination.

STIMULUS (stĭm′ū·lŭs), any cause which excites or increases action in a living organism.

STIPPLED, painted with short strokes of the brush, or having the surfaces of fresh paint roughened by being patted with the ends of the bristles of the brush.

STIPULE (stĭp′ūl), one of the pair of small, leaflike structures usually found at the base of the petiole.

STOCK, the plant which receives the scion in grafting.

STOMA, plural STOMATA, one of the many microscopic openings in a leaf, usually found in the lower surface.

STUCCO, a concrete mixture.

STYLE, the rodlike structure of a pistil connecting the stigma with the ovary.

STYLUS (stī′lŭs), the pointed part of a phonograph which cuts grooves in the wax of a master disc, or cylinder, and thus makes a permanent record.

SULFUR, a non-metallic element.

SUN, the heavenly body, around which the earth and the other planets revolve, and from which they receive light and heat.

SUNSPOT, a spot on the sun's surface, usually visible only through a telescope.

TAUPE (tōp), a dark gray or moleskin color.

TELESCOPE, an instrument used to enable the eye to see objects at a distance.

TENDRIL, of a plant, a slender leafless organ that coils spirally to support the parent plant.

TERMINAL, in electrolysis, that end of the apparatus which connects with the dry cell.

THREE-WAY SWITCH, a switch so wired with a second switch that either switch may operate the same light.

THYROID GLAND, a ductless gland, located in the neck close to the larynx, which secretes thyroxin.

TITANIUM (tī·tā′nĭ·ŭm) OXIDE, a white oxide of the metal titanium.

TITANOX, titanium oxide; used as a white paint base.

TOE-NAILED, nailed diagonally through the edge of one timber.

TOXIN, a poison produced by pathogenic germs.

TOXOID, diphtheria toxin weakened by mixing with formaldehyde or salt solution, used extensively to develop immunity to diphtheria.

TRANSFORMER, a device used to raise or lower the voltage of an alternating current.

TRANSLUCENT, permitting light to pass, but not readily enough for one to distinguish objects.

TRANSMIT, to transfer; to conduct; to act as a medium of passage for; to pass on by heredity.

TRANSPARENT, permitting nearly all the light received to pass through.

TRANSPIRATION, the passing off of water vapor from a plant, chiefly through the stomata of the leaves.

TRYPANOSOME (trĭp′ȧ·nō·sōm′), a protozoan parasite causing sleeping sickness.

TSETSE (tsĕt′sė) FLY, a fly that transmits the protozoan parasite trypanosome, infection from which causes sleeping sickness.

TUBER, a short, thickened, underground stem.

TUBERCLE BACILLI, the microorganism which causes tuberculosis.

TUBERCULIN, a vaccine of weakened cultures of the tuberculosis germ, devised by Koch in 1920 to develop immunity to tuberculosis.

TURBINE, a type of engine in which movable blades are driven by air, steam, or water.

ULTRAVIOLET, rays shorter than violet rays. They are invisible to the human eye.

UMBRA, a total or complete shadow.

UNIVERSAL MOTOR, a motor which will operate almost equally well on either direct or alternating current.

URANIUM (ū·rā′nĭ·ŭm), an element that has the properties of a metal.

UREA, a nitrogenous waste substance found chiefly in the urine of mammals.

URINE, the liquid wastes, chiefly urea dissolved in water, secreted by the kidneys and excreted through the bladder.

VACCINATION, an inoculation, usually with prepared virus, in order to induce immunity; generally speaking, the inoculation to prevent smallpox.

VACUOLE, a bubblelike structure or cavity in the protoplasm of a one-celled animal, used in excretion.

VACUUM TUBE, a tube from which the air has been exhausted. It is often used in radio work.

VAPOR, a substance in the form of a gas.

VARIABLE STAR, a star whose size appears to vary.

VEHICLE, of a paint, an oil, such as linseed oil, with which the paint base is mixed.

VENEER, a surface coating of some material that is more durable or more beautiful than the material it covers.

VIRUS (vī′rŭs), a poisonous and contagious organism or substance, apparently able to pass through the finest porcelain filters and still be capable of producing a specific disease in plants or animals.

VITAL STATISTICS, statistics relative to the births, marriages, deaths, prevalence of disease, and so on, in a community.

VITAMIN, a substance in certain foods, necessary for health and to prevent specific diseases.

VOLATILE (vŏl′ȧ·tĭl), evaporating rapidly at ordinary temperatures.

VOLCANO, a hole in the earth's crust through which molten rock and steam issue.

VOLT, the unit used to measure electrical pressure.

VOLTAGE, electrical pressure expressed in volts.

VOLTAIC CELL, a cell in which chemical energy is changed into electrical energy.

VOLTMETER, an instrument used to measure electrical pressure.

WANING (wān′ĭng), to grow smaller or weaker; to decrease.

WATER VAPOR, a diffused and vaporous form of water, such as is found in the atmosphere.

WATT, the unit used to measure electrical power.

WATT-HOUR, the unit used to measure electrical energy.

WAXES, increases, grows stronger or larger.

X RAY, a radiation which penetrates solids better than ordinary light does.

X-RAY APPARATUS, a vacuum tube used to generate X rays.

ZINC, a bluish-white element.

ZONOLITE, a kind of mica, used for insulating.

ZYGOTE (zī′gōt), a fertilized egg cell.

# Index

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